3.0 CSO Abatement Technologies

Contents

3.1 Introduction
3.2 Available Control Measures
3.3 Source Control Technologies
3.4 Collection System Controls
3.5 Storage Technologies
3.6 Wet-Weather Treatment Technologies
3.7 In-stream Oxygenation Methods
3.8 CSO Technology Screening and Evaluation
3.9 Summary

3.1 Introduction

This section describes the combined sewer overflow (CSO) control technologies and methods that Indianapolis considered to meet water quality goals. This section describes how the technologies work and how the city evaluated individual control technologies for their ability to control CSOs. The city considered many different options, including actions to reduce non-CSO pollution in Indianapolis waterways. Section 4.0 documents how the city evaluated *specific combinations* of technologies to address CSOs and other pollution sources that impair water quality.

3.2 Available Control Measures

The city strives to approach any environmental problem with a three-tiered approach. First, how can we eliminate or prevent pollution before it is created? Second, how can we reduce the volume, concentration or frequency of the pollution we can't prevent? Third, how can we best capture and treat the pollution that remains? This hierarchy of prevention, reduction, treatment is also a part of the city's overall long-term control plan for combined sewer overflows.

A combination of different control measures may be needed along each affected river or stream segment in order to reduce or eliminate CSO impacts. These measures might include technologies, operating strategies, public policies and regulations, or other measures that will help reduce water pollution. The control measures must be tailored to each waterway, taking into consideration natural conditions, unique pollution problems, costs, engineering constraints, and public input. Control measures are classified within this section into five categories that follow the prevention-reduction-treatment hierarchy:

- Point and non-point source control measures
- Collection system controls
- Storage technologies
- Wet-weather treatment technologies
- In-stream oxygenation methods

Section 3.3 outlines the city's existing source control programs. Sections 3.4 through 3.7 provide background information on control technologies the city considered. These sections describe the general categories, such as storage or treatment, and also identify some representative technologies in each category. Section 3.8 describes the methodology used to screen CSO control technologies and the results of that screening.

3.2.1 Evaluation of CSO Control Technologies

The system improvements outlined in the CSO long-term control plan (LTCP) are expected to meet water quality standards (WQS), if they are attainable, and comply with national pollution discharge elimination system (NPDES) permit requirements. The purpose of the long-term control plan is to "provide site-specific, cost-effective CSO controls that will provide for attainment of WQS."[1] The City of Indianapolis evaluated each CSO control technology for its ability to achieve the following environmental improvements:

1) Reduce both the frequency and volume of wet-weather overflows
2) Improve dissolved oxygen levels
3) Reduce bacteria
4) Reduce biochemical oxygen demand (BOD)
5) Remove settleable solids
6) Reduce floatables
7) Reduce discharges of toxic materials

The following sections identify how the city screened technologies based on their ability to meet these needs.

3.2.2 Identification of Viable CSO Control Technologies

The city evaluated available technologies and approaches to identify viable options for meeting water quality goals, CSO control goals, and infrastructure needs. **Table 3-1**, *Indianapolis CSO Control Technologies Matrix*, lists each technology considered and evaluates whether it could be used to address the city's problems. The table was reviewed and revised by the Wet Weather Technical Advisory Committee (WWTAC) (described in Section 5.5). The following sections describe some of the most viable options the city identified.

[1]U.S. EPA Combined Sewer Overflows - Guidance for Long-Term Control Plan (September 1995), Section 3.2, Page 3-3.

Table 3-1
Indianapolis CSO Control Technologies Matrix

TECHNOLOGIES	ENVIRONMENTAL IMPACTS AND IMPROVEMENTS							IMPLEMENTATION & OPERATION FACTORS
	Flow Reduction	BOD Reduction	DO Enhancement	Settleable Solids Removal	Bacteria Reduction	Floatables Reduction	Other	
SOURCE CONTROL TECHNOLOGIES								
Stormwater Management								
Catch Basin Modifications	High	Low	Low	Low	Low	High		Ongoing CSO Operational Plan; Limited by potential for street & yard flooding (Freezing Potential).
Leaching Catch Basins	Low	Low	Low	Low	Low	Low		Limited by potential for contaminating ground water;
Sump Pump Disconnect	Low	Low	Low	Low	Low	Low		Site specific; More applicable to separate sanitary system; Water has to go somewhere and new storm sewers may be required; Interaction with home owners required.
Catch Basin Cleaning	None	Low	Low	High	Low	High		Ongoing CSO Operational Plan; Labor intensive; requires specialized equipment.
Illicit Connection Control	Low	Low	Low	Low	Low	Low		Same as sump pump.
Roof Leader Disconnect Program	Low	Low	Low	Low	Low	Low		Includes area drains and roof leaders; Same as sump pump.
Oil/Water Separator/WQ Inlets	None	Low	Low	High	None	High	Toxics Reduction	Good for restaurants, gas stations and parking lots; highway drainage; Site specific; Labor intensive.
Swales & Filter Strips	Low	Low	Low	Low	Low	High		Site specific; Good BMP; Low operational cost.
Porous Pavement	Low	Low	Low	Low	Low	Low		Not durable and clogs in winter; Oil and grease will clog; High maintenance and related costs.
Parking Lot Storage	High	Low	Low	Low	Low	High		Limited by potential for lot and yard flooding (Freezing Potential); Low operational cost.
Street Storage (Catch Basin Inlet Control)	High	Low	Low	Low	Low	High		Example - Evanston, Illinois; Limited by potential for lot and yard flooding (Freezing Potential) causing hazardous driving conditions; Low operational cost.
Solid Waste Collection/Disposal								
Illegal Dumping Control	None	Low	Low	Low	Low	High		Ongoing CSO Operational Plan; Enforcement of current law requires large number of code enforcement personnel; Recycling sites maintained.
Solid Waste Public Education	None	Low	Low	Low	Low	High		Ongoing CSO Operational Plan; Ongoing City Commitment.
Hazardous Waste Collection	None	Low	Low	Low	Low	Low	Toxics Reduction	Ongoing CSO Operational Plan; Disposal through existing "Tox-Away Day" collection.
Public Education								
Water Conservation	Low	None	None	Low	Low	Low		Coordinate with Water Company.
Catch Basin Stenciling	None	None	None	None	None	High	Toxics Reduction	Inexpensive; Easy to implement; Public education potential.
Community Cleanup Program	None	None	None	None	None	High		Inexpensive; Sense of community spirit; Educational BMP; Aesthetic Enhancement.
Public Education Programs	None	None	None	None	None	High	Toxics Reduction	Ongoing CSO Operational Plan; Increase City commitment.
Recycling Programs	None	None	None	None	None	High	Toxics Reduction	Ongoing CSO Operational Plan; Ongoing City commitment.
Animal Waste Management	Low	Low	Low	Low	Low	None		Ongoing; Site specific.
Lawn & Garden Maint.	None	None	None	None	None	None	Toxics Reduction	Ongoing CSO Operational Plan; Changes in use of herbicide products and fertilizers.
Adopt-A Stream	None	None	None	None	None	High		Aesthetic Enhancement; Sense of community; Provide better patrol of stream and corresponding banks; coordinate with DNR.
Warning Signage	None	None	None	None	None	None		Ongoing CSO Operational Plan; Public Health Notification; Low O& M Costs.

Table 3-1
Indianapolis CSO Control Technologies Matrix (continued)

TECHNOLOGIES	ENVIRONMENTAL IMPACTS AND IMPROVEMENTS							IMPLEMENTATION & OPERATION FACTORS
	Flow Reduction	BOD Reduction	DO Enhancement	Settleable Solids Removal	Bacteria Reduction	Floatables Reduction	Other	
SOURCE CONTROL TECHNOLOGIES								
Construction Related								
Onsite Control/New Construction	None	None	None	High	None	High		Contractor or owner pays for erosion control; Reduces clogging of catch basins; Reduces sediment and silt loads to stream; Little O & M for City.; Enforcement.
Soil Stabilization Measures	None	None	None	High	None	None		Construction Associated; Ongoing; In building code; Reduces silt loads to stream; Enforcement.
Stabilized Construction Entrance	None	None	None	High	None	None		Ongoing; In building code and related City construction projects specifications; Enforcement.
Good Housekeeping								
Storage/Loading/Unloadin-g Areas	None	Low	Low	Low	None	Low	Toxics Reduction	Industrial Facilities; Only applies to industry.
Industrial Spill Control	None	High	High	Low	Low	Low	Toxics Reduction	Ongoing CSO Operational Plan; Pretreatment Program regulated by State and City.
Street Sweeping Programs	None	Low	Low	High	Low	High		Labor intensive; Specialized equipment; Doesn't address flow or bacteria.
Litter Ordinance Enforcement	None	None	None	None	None	High		Ongoing CSO Operational Plan; Aesthetic Enhancement; Labor intensive.
Vehicle (Yards) & Equipment Management	None	None	None	None	None	None		Aesthetic Enhance; Labor intensive for monitoring and compliance activities.
Miscellaneous								
Review Industrial Pretreatment Program	Low	High	High	High	Low	High	Toxics Reduction	Ongoing CSO Operational Plan and Ind. Pretreatment Program.
Streambank Stabilization/Restorations	None	None	High	Low	None	None		Restoration of Streambanks; Aesthically Enhances Stream; Canopy growth provides cool temps; Block U.V.; Reduce Greenway O & M.
Septic Tank Improvements / Barrett Law	None	High	High	Low	High	None		Important for bacteria reduction in localized areas and in streams during dry weather periods; Reduce homeowner O & M.
COLLECTION SYSTEM CONTROL								
O&M / Repair								
Infiltration/Inflow Reduction	High	Low	Low	Low	Low	Low		Controlling infiltration might have minimal impact on CSO volume due to its small magnitude when compared to inflow; Labor intensive; Requires specialized equipment; Particularly effective in separated sewer areas; Ongoing O & M.
Regulator Improvement Program	Low	Low	Low	Low	Low	High		Ongoing; CSO Operational Plan; Relatively easy to implement; mechanical controls requires O & M.
Sewer System Cleaning / Flushing	Low	High	Low	High	Low	High		Ongoing; CSO Operational Plan; Maximizes existing collection system; Reduces first flush effect; Labor intensive.
Sewer / Regulator Maintenance	None	None	None	None	None	High		Inspection, removal of debris and increased flow to plant; Inspected and assessed approximately 350,000 feet of combined sewer 48" and larger; Ongoing CSO Operational Plan and O & M.
Outfall Maintenance Program	None	None	None	None	None	Low		Installed flap valves and duckbill valves reducing stream intrusion into sewer collection system; Ongoing O & M.
House Lateral Repairs	High	Low	Low	Low	Low	None		House laterals account for 1/2 the sewer system length and significant sources of I & I; Repairs by homeowners.
Engineering / Structural								
Real Time Control	High	High	High	High	High	Low		Highly automated system; Mechanical control requires O & M; Increases potential for sewer backups
Sewer Separation	High	Low	Low	Low	Low	High		Disruptive to local neighborhoods; Effectiveness of separation has been reassessed in recent years. Results show increased loads of storm water runoff pollutants (Sediments, bacteria, oil and metals).
Outfall Consolidation / Relocation	Low	Low	Low	High	Low	High		Directs flow away from specific area; Low operational cost; May reduce permitting/monitoring; Can be used in conjunction with storage & treatment technologies.

Table 3-1
Indianapolis CSO Control Technologies Matrix (continued)

TECHNOLOGIES	ENVIRONMENTAL IMPACTS AND IMPROVEMENTS							IMPLEMENTATION & OPERATION FACTORS
	Flow Reduction	BOD Reduction	DO Enhancement	Settleable Solids Removal	Bacteria Reduction	Floatables Reduction	Other	
STORAGE TECHNOLOGIES								
Storage Before Sewer								
Industrial Discharge Detention	Low	High	High	High	Low	High	Toxics Reduction	Industry to hold stormwater or combined sewage until after the storm; Example - Indianapolis International Airport and Indianapolis Water Company.
Dry Detention Basin	High	Low	Low	Low	Low	High		Siting and land requirements make location selection difficult; Good approach during reconstruction of facilities in congested areas.
Wet Detention Pond	High	Low	Low	High	Low	High		Siting and land requirements make location selection difficult; Good approach during reconstruction of facilities in congested areas.
Storage in Sewer System								
In-Line Storage - Interceptor	High	High	High	High	High	High		Increased O & M costs; Increased potential for basement flooding; Maximizes use of existing facilities.
In-Line Storage - Trunk Sewer	High	High	High	High	High	High		Increased O & M costs; Increased potential for basement flooding; Maximizes use of existing facilities.
Off-Line Storage								
Tunnels	High	High	High	High	High	High		Eliminates land restrictions and costs associated with storage basins; Tunnels can provide large storage volumes with relatively minimal disturbance to the ground surface which can be very beneficial in congested urban areas; Increased O & M costs.
Off-Line Covered Storage Basins	High	High	High	High	High	High		Includes variations of retention; detention and flow-through systems; Requires large area for location of underground basin; Increased O & M costs; Potentially high neighborhood disturbance.
Off-Line Open Storage Basins	High	High	High	High	High	High		Includes variations of retention, detention and flow-through systems; Example - Louisville, Kentucky; Requires area for location of above-ground basin; Increased O & M costs; Odor issues are a consideration.
TREATMENT TECHNOLOGIES								
At CSO Facility								
Vortex Separators	Low	*	*	High	Low	High		* BOD reduction and D. O. enhancement varies widely; Increased O & M costs.
Vortex Separators w/ disinfection	Low	*	*	High	High	High		Example - Columbus, Georgia; * BOD reduction and D. O. enhancement varies widely; Increased O & M costs.
High Rate Treatment	High	High	High	High	None	High		Currently being piloted in Ft Worth, TX and Rochester, NY; Examples - Actiflo, Densadeg, Microsep; High O & M costs; limited ammonia removal.
High Rate Treatment w/ disinfection	High	High	High	High	High	High		Currently being piloted in Ft Worth, TX and Rochester, NY; Examples - Actiflo, Densadeg, Microsep; High O & M costs; limited ammonia removal.
Mechanical Screens	None	None	None	None	None	High		Mechanical devise requires additional O & M.
Netting Systems	None	None	None	None	None	High		Labor intensive.
Existing Treatment Facility								
Maximize Flow to AWT Plants	High	High	High	High	High	High		CSO Operational Plan implemented 26 improvements (e.g., Pleasant Run, Pogues Run and Fall Creek Intereceptors); Low O & M cost.
Increase/Primary Treatment	High	High	High	High	High	High		Increased O & M costs.
Increase/Secondary Treatment with Disfection	High	High	High	High	High	High		Higher level of treatment; Eliminate primary effluent bypass; High O & M costs.
Equalization / Open Storage	High	High	High	High	High	High		Limited space onsite at Belmont AWT; Additional storage options in mines and areas near both AWTs; Odors must be monitored.
New Treatment Facility								
Increase Overall AWT Capacity	High	High	High	High	High	High		Possible new reclamation facility on Fall Creek; High O & M costs; Minimize odors by processing solids at Belmont AWT.
In Stream								
Stream Dam Modification/ Removal	None	None	High	None	None	None		Remove old dams; No additional O & M.
Sidestream Aeration	None	None	High	None	None	High		Includes screening; Example - SEPA Project (Chicago); High O & M.

3.3 Source Control Technologies

The following discussion briefly outlines the city's existing source control programs. More detailed information on specific alternatives considered is contained in Section 4.0 and recommended plans for installing source controls are contained in Section 7.0 of this report.

Sewer Service for Unsewered Areas: Failed septic systems can leach bacteria, biological oxygen demand (BOD) and ammonia into local ditches and streams. Connecting these areas to sanitary sewers reduces these pollutant loads during both dry and wet weather.

Industrial Pretreatment: For most stream segments in Indianapolis, industrial pollution is not the most significant pollution problem. However, where industries discharge into the combined sewer system, their contaminants can wash into waterways through CSOs. Indianapolis' existing pretreatment program works to reduce these loadings into the environment. The city is considering a number of alternatives for reducing the impact of CSO discharges containing industrial wastewaters. Some of these alternatives include requiring industrial users to decrease, hold, or divert flows during wet-weather events; eliminating clear-water flows; reducing daily discharges; upgrading pretreatment requirements; revising pretreatment limits; increasing fees; and requiring stormwater permits in the CSO area.

Improved Stormwater Drainage: Improving drainage can reduce stormwater inflow into the sewer system, improve existing septic system performance, and reduce road maintenance and capital costs. The city has developed a Stormwater Master Plan to address drainage and related water quality issues. The city has implemented new regulations to control and treat stormwater runoff from new construction and redevelopment sites. The city is exploring innovative approaches to controlling and treating stormwater through advances in best management practices (BMP) and technologies such as modular stormwater reclamation and reuse systems. Best management practices seek to preserve natural filtration and pollution removal, such as by planting buffer strips. The city continues to review innovative technologies for reclaiming and managing stormwater flows before they enter the combined sewer system.

Stream Bank Restoration: Restoring stream banks to more natural conditions can improve water quality, natural beauty and wildlife habitat. Restored stream banks also can improve dissolved oxygen levels and reduce stream temperatures. These activities are most effective along smaller streams.

Sediment Removal in Streams: Sediments are naturally occurring substances on a streambed generated by soil erosion. Sludges are found in sediments when sewage solids settle on the bottom of a stream. Often, removing sediments and sludges creates short-term environmental problems by stirring up the pollutants buried in the streambed. Nature can often remedy these problems on its own, but new sediment and sludge loads must be reduced for this to happen.

Construction Related Controls: When land is cleared for new construction, soils can be washed away into rivers and streams. Federal, state and city regulations require soil erosion control at construction sites.

Housekeeping Practices: Stormwater running off streets, parking lots, and other surfaces can carry solids, oils, grease, industrial chemicals and other pollutants into waterways. Housekeeping practices seek to reduce the amount of pollutants that can be washed away. Examples include street sweeping, litter control, and vehicle and equipment maintenance.

Public Outreach: Public outreach helps raise citizens' awareness of water quality and other environmental issues. It can also encourage people to do their part to reduce pollution entering our waterways.

Watershed Planning Initiative: In order to meet water quality standards, many local and state government organizations along the White River need to coordinate activities. The city is working with a regional watershed alliance to address water pollution and its many causes.

3.4 Collection System Controls

Collection system controls seek to reduce or better manage the flow within the sewer collection system. As described in the *CSO Operational Plan* (DPW-ICST, 2003), the city's early action projects include improvements to regulators within the system, installation of real-time control (RTC) devices, installation of in-line storage devices, infiltration and inflow improvements, localized sewer separation, and sewer system cleaning and flushing.

3.4.1 In-Line Storage (With Real-Time Control)

In-line storage uses the existing pipe capacity of combined sewer trunks and interceptors to temporarily store combined sewage generated by a storm. Inflatable dams or mechanical gates are used to hold sewage in a pipe or sewer trunk. Examples are shown in **Figures 3-1** and **3-2**. When available, in-line storage can be a low-cost way to reduce the volume of CSOs reaching receiving waters.

In-line storage can increase or possibly maximize the flows carried in interceptor networks to the wastewater treatment plant. In-line storage also can reduce the required level of additional CSO controls; capture the heavy pollutant load in the first flush; and optimize combined sewer flows treated at the wastewater treatment facility. The benefits of RTC in sewer systems are often not limited to CSO volume reduction. RTC may play an important role in the following aspects of maintenance/operations:

- Responding to emergency situations and conditions (during either wet- or dry-weather periods) including power loss, infrastructure damage, or equipment failure
- Isolating parts of the system for maintenance or construction
- Reducing energy consumption
- Maintaining flow regime and (sewage) velocities that will prevent/reduce sediment deposition
- Minimizing the wear/tear on equipment
- RTC uses the fill/decant cycles of the entire system to improve storage capacity. By making better use of the existing capacity, the city can reduce spending on new storage facilities. Additionally, by controlling the flow within the system, peak rainfalls are managed and treated better. Real-Time Control also can be used to provide control of existing lift stations and future off-line storage structures, creating a global control system that can optimize the city's capacity to predict and control sewage overflows.

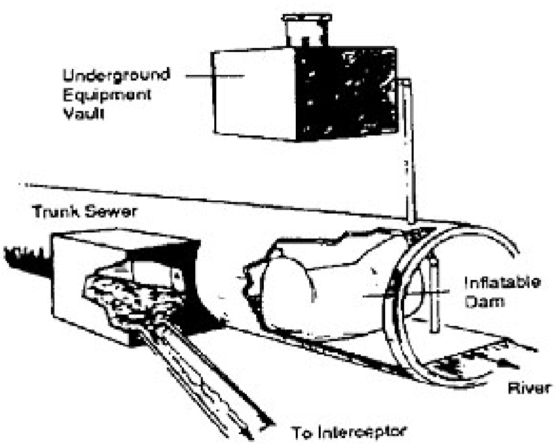

Figure 3-1
Inflatable Dam *(U.S. EPA, 1993)*

Real-time control also can prioritize overflows in one area over another, balance the hydraulic load in the collection system, reduce backup flows, provide dynamic and stepped storage, manage specific flow constraints, and provide fast dewatering of in-line and off-line storage facilities.

A disadvantage to in-line storage is the potential for either basement or surface flooding, which poses a risk to both public health and safety. To reduce this risk, the system needs emergency procedures and a reliable safety mechanism, which monitors and controls the flow of wastewater during a storm.

Another disadvantage of in-line storage is the potential to accelerate structural failure of the combined sewer system. Larger storage capacities are often found in the oldest sections of a combined trunk sewer system. Over time, these sewers may have deteriorated and become susceptible to collapse. Therefore, the city assesses the structural conditions of pipes when identifying locations for in-line storage.

In-line storage could potentially cause septic odors, although no such problems have been reported in other cities. Residual solids and floatables might stick to the high sides of the combined sewer when wastewater is allowed to drain back into the interceptor system. Those solids would not be flushed out of the system during normal dry-weather flows, thereby presenting potential odor problems.

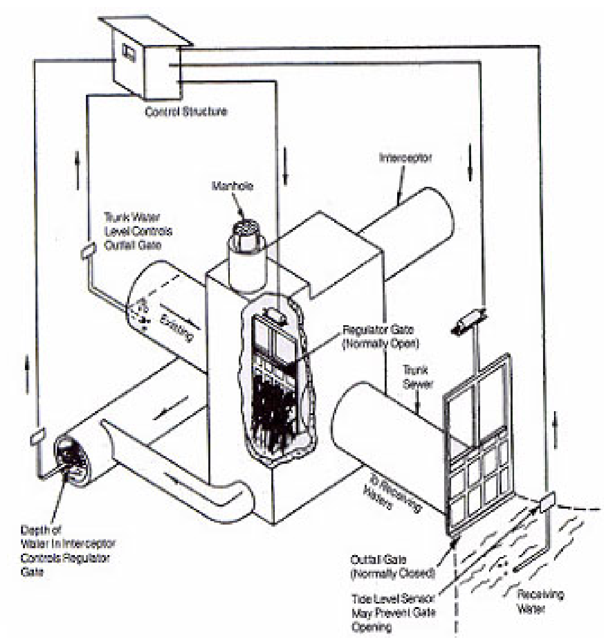

Figure 3-2
Motor-operated Gate Regulator
(U.S. EPA, 1993)

In-line storage with real-time control often proves to be a less expensive method to create storage than other technologies. Options considered by Indianapolis are evaluated in more depth in Section 4.

Advantages: Highly automated system that makes better use of existing sewage collection network. Potential for cost savings by utilizing existing pipeline capacity to increase combined sewage storage capacity. Can reduce cost of building new storage facilities. Effective for small, localized rainfall events.

Disadvantages: Increases potential for sewer backups, odor, and structural failures. Less effective for large rainfall events because the collection system is needed for conveyance. Increased operation and maintenance costs due to additional cleaning, odor and corrosion control requirements.

3.4.2 Inflow/Infiltration Abatement

Inflow and infiltration (I/I) is stormwater and ground water that enters a sanitary sewer system. *Inflow* is water entering a sewer system through roof drains, manhole covers, cross connections from storm sewers, catch basins, and surface runoff. *Infiltration* comes from ground water that seeps in through defective pipes, pipe joints, connections, or manhole walls.

I/I reduction can contribute to the city's long-term control plan by removing clear water from the upstream sanitary sewers, thereby relieving demands in the downstream interceptors and wastewater treatment plants. The city's I/I abatement program seeks to refurbish existing sewers and reduce combined sewer overflows.

The best time to control infiltration and inflow into sewer systems is during sewer construction. A "tight" system can substantially reduce or even eliminate overloaded and surcharged sewers. Good I/I controls also can save money by extending the life of the system, reducing the need for expansion, and lowering operating costs.

Advantages: Helps reduce volume of water entering a system, especially in separated sewer areas. Can reduce the need to build additional capacity. Can reduce sewer backups. By reducing the amount of flow, can extend the life of sewer system and lower operating costs.

Disadvantages: Identifying I/I problems is labor intensive. Requires specialized equipment and ongoing maintenance.

3.4.3 Localized Sewer Separation

Separation is the conversion of a combined sewer system into separate stormwater and sanitary sewers. Separated sewers reduce flows to the wastewater treatment plants by eliminating excess flow from surface runoff during wet-weather periods. While this technology was historically considered the ultimate answer to CSO pollution control, it has lost favor in recent years due to its especially high cost and the major disruptions it creates to traffic and other daily community activities. In addition, sewer separation would greatly increase the discharge of urban stormwater runoff, which contains a variety of pollutants such as sediments, organic matter, bacteria, metals, oils, floatables, and so on. Some stormwater is treated at the wastewater treatment plant when captured in a combined sewer.

Several potential benefits of sewer separation may warrant its consideration in localized areas. These include:

- Reducing upstream flooding and overflows in cases where the existing combined sewers are undersized and back up frequently during storm events
- Providing a more effective and economical option than treatment facilities in remote segments of a combined sewer system serving relatively small areas

Advantages: Eliminates CSOs and prevents untreated sanitary sewage from entering receiving waters. Reduces volume of flow at treatment plant.

Disadvantages: Cost and disruption to community. Requires work on private property. Separated stormwater in urban areas carries many pollutants that would go untreated. Complete separation is difficult to accomplish, whether the combined system is converted into a sanitary sewer or a storm sewer, due to inflow, infiltration, illicit connections and other factors.

3.5 Storage Technologies

Storage technologies provide additional capacity to the system, thus reducing the frequency and volume of combined sewer overflows. Stormwater can be stored before it reaches the sewer (as in detention ponds). Combined sewage can be stored in the system itself, or it can be diverted to an off-line storage tunnel or basin. The following sections describe some technologies that Indianapolis has considered.

3.5.1 Off-line Storage/Sedimentation Tanks

Off-line storage tanks store all or part of the CSOs that occur during wet weather. Later, when system capacity becomes available, flows can be sent to the treatment plant. If flows exceed the storage capacity, they will receive some solids separation (and disinfection, if available) before leaving the storage facility.

The size of an off-line storage tank depends upon the capture goals set for each site. Typical CSO control goals include:

- Providing a minimum treatment level for flows up to a specified point
- Fully capturing the first flush and providing partial treatment for later flows
- Reducing the number of annual overflow events and/or volume of overflow

A typical arrangement, shown in **Figure 3-3**, includes a regulator, bar screens, settling tank and outfall. If disinfection is considered, it may be implemented either upstream or downstream of the settling tank. Design details such as flow distribution, tank flushing, and facility activation also are affected by the overall goal and hydraulics of the specific site.

Storage tanks are generally fed by gravity and the stored flow is typically pumped back to the interceptor after the storm. If the existing sewers are deep, then the storage tank is deep and construction becomes more expensive.

Advantages: Well suited for early action projects at critical CSO outfalls. Reduces the frequency and volume of overflows at a specific CSO outfall or group of CSO outfalls. Captures the most concentrated first flush portion of CSO events. Reduces the size of downstream conveyance and treatment facilities.

Disadvantages: Relatively high cost compared to the volume captured. Operation and maintenance costs can be high, especially if the application includes provisions for partial treatment and discharge, rather than simple storage and bleed-back to the sewer. Depending on the application, there may be a potential for odor problems.

3.5.2 Storage Tunnels

Deep tunnels capture wet-weather overflows from a system of CSO outfalls within a large geographic area. They are generally constructed in bedrock several hundred feet below the ground surface. They provide a large storage volume with minimal disturbance to the ground surface and convey the captured CSO to a central location. Deep tunnels are generally the preferred technology in densely developed urban areas such as Indianapolis.

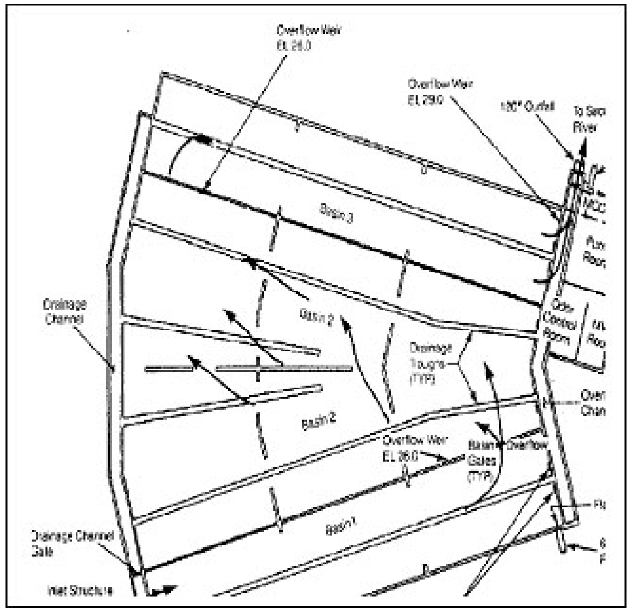

Figure 3-3
Pioneer Reservoir Normal Fill and Overflow Path *(WPCF, 1989)*

Although tunnel construction is challenging, the technology has matured during recent years as numerous installations have been completed. It requires providing work shafts, access structures, vent shafts and drop structures, along with a disposal site for excavation materials. All of these require some disturbance on the surface.

The three most common ways to excavate this type of tunnel are tunnel boring machines, rock header machines, and drill-and-blast methods. Along with the tunnel, a pumping station also must be built to dewater the tunnel to the treatment plant. CSO storage tunnels have been installed in several cities, including Chicago, Milwaukee, Rochester (NY) and Toledo. An example of this technology is shown in **Figure 3-4.**

Advantages: Large volume of storage with minimal surface disturbance. Can build within existing rights of way. Inoffensive to adjacent property owners. Low maintenance cost relative to open surface storage facilities. Also serves as conveyance facility. Minimizes purchase of large parcels of ground.

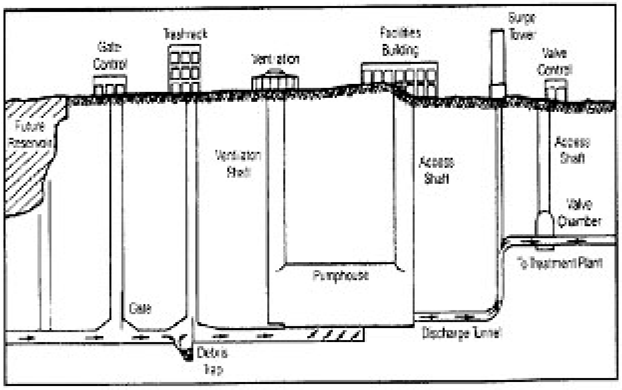

Figure 3-4
Chicago TARP Tunnel *(WPCF, 1989)*

Disadvantages: Higher construction costs than open storage facilities. However, the relative cost is dependent on subsurface conditions.

3.6 Wet-Weather Treatment Technologies

Wet-weather treatment technologies are used to remove pollutants from incoming wastewater before it is discharged to the receiving stream. Wet-weather treatment technologies can be used at an individual CSO outfall, at CSO storage facilities, or at an existing or new wastewater treatment facility. Descriptions of technologies considered by the City of Indianapolis are provided below in three categories:

1) Treatment plant technologies
2) Disinfection technologies
3) CSO outfall technologies

3.6.1 Treatment Plant Technologies

To meet long-term wet-weather treatment goals, the city will need to provide additional wet-weather treatment capacity at its Belmont and Southport AWT plants. Technologies considered for wet-weather treatment include:

- Conventional primary clarification (physical treatment)
- Advanced primary clarification (physical/chemical treatment)
- Secondary Treatment (biological treatment)

3.6.1.1 Conventional Primary Clarification

Conventional primary clarification is a physical process that settles solids out of previously screened wastewater. Used at a majority of municipal wastewater plants, this device settles, concentrates and removes solids while allowing clear wastewater (primary effluent) to be discharged for further treatment.

Conventional primary clarification is moderately effective at removing suspended solids and BOD. Typical primary treatment at municipal facilities achieves about 60% removal of suspended solids and 35% removal of BOD. Due to its simplicity and built-in capacity for accumulating settled solids, conventional primary clarification provides a cost-effective method for removing total suspended solids (TSS) and BOD. Accordingly, the city is constructing an early action wet-weather project to expand the Belmont AWT plant primary clarifiers. An additional early action project is planned to expand wet-weather primary clarification at the Southport AWT plant. In addition, wet-weather provisions for expanded primary clarification at the Southport AWT facilities have been planned (ICST, 2004).

Advantages: Moderately efficient at removing suspended solids and particulate BOD. Provides significant storage capacity for settled solids. Produces a relatively thick settled sludge of low volume. Lower operation and maintenance cost than enhanced high-rate clarification or secondary treatment. Easy to expand.

Disadvantages: Requires more land for construction than high-rate versions of advanced primary clarification (referred to as enhanced high-rate clarification, EHRC). Less efficient than advanced primary treatment at removing TSS and particulate BOD.

3.6.1.2 Advanced Primary Clarification

Enhanced high rate clarification (EHRC) is a form of advanced primary clarification. Although there are several variants of advanced primary clarification processes, all of them rely on the addition of a chemical coagulant such as ferric chloride or alum to achieve greater suspended solids removal than conventional primary clarification. Advanced primary clarification is thus a physical-chemical treatment process. EHRC employs lamella type clarifiers with or without ballasting agents such as micro-sand so that very small units can provide effective suspended solids removal at very high flowrates. One type of EHRC process is illustrated in **Figure 3-5**. Versions of advanced primary treatment employ conventionally sized clarifiers but with supplemental rapid mix tanks and flocculation tanks for chemical addition and coagulation of the raw suspended solids. All such processes remove suspended solids by simple gravity settling and generate a settled sludge stream for further processing. EHRC facilities generate substantially more sludge than conventional primary clarifiers, both because the removal efficiency is higher and because of the large amount of chemical solids generated from chemical addition. The settled sludge solids also do not thicken as well as sludge solids from conventional primary clarifiers.

There are several additional benefits of advanced primary treatment processes, including:

- The chemical coagulants typically used are effective in removing phosphorus (though such removal is not required).
- The iron hydroxide or aluminum hydroxide precipitant formed can be effective co-precipitating agents for trace removal of regulated metals.
- The mild acidity of the chemical reagents can slightly lower the pH of the treated effluent and thereby reduce the concentration of unionized ammonia in the effluent.

Accordingly the City of Indianapolis has evaluated advanced primary treatment, including EHRC, for several different applications:

- End of Pipe Treatment: An EHRC facility could be located at an individual CSO discharge point or at a point where several CSOs are consolidated to treat combined sewage before it overflows into the receiving stream.

- Peak Shaving Treatment: An EHRC facility could be used to treat combined sewage that would otherwise be discharged to the stream once storage facilities reach maximum capacity during a wet-weather event. Specific applications of this concept are evaluated in Section 4.

- Wet-weather Treatment at the AWT plants: Advanced primary treatment processes, including EHRC, could be located at the Belmont and Southport AWT plants to treat wet-weather flows in excess of the AWT treatment capacity. Concepts under consideration include: (1) intermediate clarification of the first-stage biological effluent at the Belmont plant; (2) clarification of raw sewage at the Belmont headworks during extreme wet-weather events; and (3) clarification of captured CSO from a proposed deep tunnel during extreme events that exceed expanded biological treatment capacity. See Section 4 for the evaluation of these alternatives.

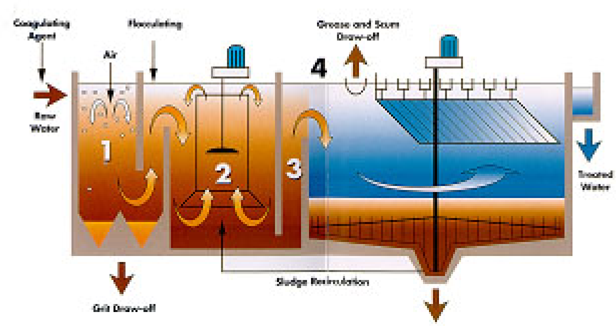

Figure 3-5
Enhanced High Rate Clarification (EHRC) System *(IDI, 1999)*

EHRC has been demonstrated to be very effective at removing suspended solids, with effluent suspended solids concentrations similar to that which can be achieved by suspended growth biological treatment systems (around 20 to 30 mg/L). However, in contrast to biological treatment processes, advanced primary clarification does not remove soluble biodegradable organics. Because the raw sewage at the Belmont plant has a relatively high soluble BOD fraction, total BOD removals from advanced primary clarification would be considerably less than the 50-80 percent reported in the literature.

The city conducted a six-month pilot test at the Belmont AWT plant in 2003 to evaluate alternative processes for advanced primary treatment. The main application tested was for removing suspended solids from an existing first-stage biological process (bioroughing towers) where the soluble BOD is low. The second application tested was for removal of suspended solids from wet-weather overflows at the headworks of the Belmont facility. Pilot plant testing applied to the Belmont first-stage bioroughing system (BRS) effluent in 2003 showed that several variants of advanced primary treatment can reliably achieve effluent suspended solids concentrations equivalent to conventional secondary treatment criteria. Chemical addition of ferric chloride or other coagulants such as alum could be required.

Advantages: Highly efficient at removing suspended solids and particulate BOD. The high-rate technologies require relatively little space. Easy to test and expand. Start-up is relatively fast, taking only about 20 minutes. Reported capital cost savings are said to greatly exceed the increased operating costs, which are incurred only during peak flow events, typically lasting for relatively short and infrequent periods.

Disadvantages: Disadvantages of the EHRC process include the need to frequently start up and shut down the equipment, the need to have an in-plant storage basin for the start-up period, ineffectiveness at removing soluble BOD and ammonia, and increased sludge generation rates from the chemical solids produced and the comparatively poor thickening characteristics of the solids. High rate variants, i.e. EHRC, have essentially no sludge storage capacity and thus would require the addition of large tankage for thickening and storing the solids prior to sludge dewatering, stabilization, and disposal.

3.6.1.3 Secondary Treatment

Secondary treatment systems receive the clarified effluent from conventional primary treatment for biological removal of soluble BOD, as well as remaining suspended solids and particulate BOD (the BOD associated with the suspended solids). Because of the effectiveness of biological treatment for removing soluble organics, secondary treatment provides better effluent quality than advanced primary clarification when treating wet-weather flows. Concepts for essentially doubling the biological treatment flow capacity for the Belmont and Southport facilities have been developed. In evaluating these systems, the city considered these factors:

- Performance comparisons of alternative technologies for primary treatment, advanced primary treatment, conventional biological treatment (BOD removal), and advanced biological treatment (BOD and ammonia removal)
- Existing effluent limits in the city's wastewater NPDES permit and modifications of those limits during wet weather
- Space requirements (the Belmont site has limited space in which to construct new facilities)
- The ability to handle the significant fluctuations in both flow and pollutant loadings associated with wet-weather flows
- Future growth within the service areas

As explained below, the high-flow biological treatment process considered for the Belmont plant differs from that considered for the Southport facility.

3.6.1.3.1 Belmont High-Flow Biological Treatment Process

The existing Belmont facility includes two stages of biological treatment that operate in series. The first stage is an attached growth biological roughing process in which biomass (bacteria) grow attached to the surface of plastic media within large vertical towers. The roughing process effectively removes soluble biodegradable organics (BOD) by conversion to biomass. Excess biomass sloughs off the media and enters the second stage biological process. The second stage is a high purity oxygen activated sludge nitrification process for removing ammonia and the remainder of the soluble BOD.

The city will be modifying the two-stage process by upgrading the first-stage to a very cost-effective trickling filter /solids contact (TF/SC) process. In this manner, the first stage would become a secondary treatment process. During dry weather, about half of the primary effluent will be treated by the TF/SC process and then combined with the other half of the primary effluent for second stage biological nitrification treatment. During wet weather, the secondary effluent from the TF/SC process would be progressively uncoupled from the second stage nitrification process as wet-weather flowrates escalate beyond the flow capacity of the second stage. At the extreme condition, the two stages would be completely uncoupled and operated in parallel rather than in series, with the first stage providing secondary treatment of half the wet-weather flow; and the second stage providing advanced treatment for the other half of the wet-weather flow. Collectively, the biological treatment capacity during wet weather would be about twice the current capacity.

Advantages: Advantages include adapting the existing two-stage biological treatment system to double the biological treatment flow capacity during wet weather. Effluent quality would be superior to stand-alone physical-chemical treatment technologies because soluble BOD is efficiently removed. Moreover, the process could be designed and operated to operate on-line continuously (without chemical addition during dry weather). This would reduce the amount of solids imposed on the second-stage nitrification process, thereby reducing oxygen requirements and energy consumption and/or increasing the capacity of the second stage process for future growth.

Disadvantages: Solids generation would impose a significant additional load on the existing solids processing facilities. The space requirement may or may not be larger than that required for a stand-alone EHRC process. Would require modification to NPDES permit.

3.6.1.3.2 Southport High-Flow Biological Treatment Process

An alternatives analysis was completed in 2004 for expanding the Southport facility to relieve the Belmont plant from the burden of having to treat captured CSOs. Like the

Belmont facility, the Southport facility flowsheet includes the same two stages of biological treatment. The facility includes an older air activated sludge system with a nitrification capacity of only 30 mgd. The existing volume of the aeration tankage is relatively large (in fact, considerably larger than the 120 mgd oxygen nitrification process tankage). With the addition of efficient oxygen transfer equipment and much larger secondary clarifiers, it is believed that effective treatment can be achieved at flowrates up to 150 mgd.

As an ancillary benefit, the process will relieve the Belmont plant of about 25 mgd in order to provide enough flow during dry weather to keep the Southport process viable and ready to treat wet-weather surges in flow. Therefore, this will provide capacity at the Belmont plant for future growth within the service area.

Advantages: Highly efficient at removing soluble BOD, particulate BOD and suspended solids. Anticipated to be effective at removing ammonia at flowrates up to about 120 mgd. Requires relatively little new space because the new clarifiers would fit in the same space currently occupied by the existing secondary clarifiers.

Disadvantages: Increased operation and maintenance costs over primary or advanced primary treatment.

3.6.2 Disinfection Technologies

Seasonal disinfection is required from April 1 through October 31 at the Southport and Belmont AWT plants before discharge to the White River. In accordance with the terms of the NPDES discharge permits, traditional monthly/weekly numerical effluent limits for fecal coliform bacteria will be replaced with monthly/daily numerical limits for *E. coli* bacteria. Sodium hypochlorite is currently used for disinfection at the Belmont and Southport AWT plants, followed by sodium bisulfite for dechlorination. However, a rehabilitation project is underway to return to ozone disinfection at both plants.

Disinfection also can be used at CSO outfalls to treat discharges. Currently, none of the city's CSOs are equipped for disinfection. Disinfection systems can remove more than 99.99 percent of the total coliforms after treatment of flow from CSOs. To be cost-effective, disinfection should be applied after solids are removed from the wastewater stream. The city evaluated several technologies for disinfection in the CSO system. These include ultraviolet (UV) disinfection, ozonation, chlorination/dechlorination, and peracetic acid.

The following discussion of disinfection technologies is based on several technical papers including *High-rate Disinfection Techniques for Combined Sewer Overflow* (Stinson and others, 1999) and "Disinfection Efficiency of Peracetic Acid, UV and Ozone after Enhanced Primary Treatment of Municipal Wastewater" (Gehr and others, 2003).

Selecting the best disinfection technology for a specific site involves looking at a number of factors. Criteria to consider include effectiveness, public safety, aquatic toxicity, application to low-quality effluent, required contact time, and cost-effectiveness. Permit limits are also a factor in choosing the city's disinfection approach.

3.6.2.1 Ultraviolet Disinfection

Ultraviolet radiation lamps kill bacteria in water without adding any chemicals. It is the most common alternative to chlorination for wastewater disinfection. Its safety and other advantages have led researchers to look into its possible use for combined sewage overflows. The Columbus Water Works in Columbus, Georgia examined the performance of various wet-weather treatment technologies for the control of CSOs, including UV disinfection. A UV disinfection system using medium pressure, high intensity lamps was located downstream of a filter. The UV system consisted of two banks of 42 bulbs each. Contact times were generally less than two seconds.

Bacteria kill is a function of lamp intensity, contact time (flow), pretreatment quality (light transmittance, TSS, chemical oxygen demand (COD), and ammonia) and temperature. Filter effluent (UV influent) had a transmissivity between 20 and 60 percent. The media filter provided sufficient pretreatment, allowing the UV system to reduce bacteria counts to hundreds or thousands of colonies per 100 mL for flows of 10 to 20 mgd, respectively. These results were for average conditions of TSS at 50 mg/L, 20 percent light transmittance and 25 degrees Celsius water temperature.

The study concluded that UV disinfection of filtered CSO is cost-effective and environmentally sensible for the smaller, more frequent CSO events. The study suggested combined chemical and UV disinfection for more reliable and effective CSO application.

In addition to the Georgia study, four high-rate disinfection technologies, including UV, were pilot-tested to determine their effectiveness in reducing bacteria levels at the Spring Creek, New York wastewater facility. During concurrent side-by-side testing, samples of the influent wastewater and treated effluent from each pilot were collected and analyzed for bacteria and conventional wastewater quality parameters. This study yielded the following observations:

- UV disinfection effectiveness tended to decrease at higher TSS concentrations (TSS greater than 150 mg/L).
- UV and chlorine dioxide technologies provided nearly complete reductions of bacteriophage and naturally occurring enteroviruses as found in wastewater at concentrations on the order of 106 plaque-forming units (pfu)/mL.
- UV disinfection has the distinct advantage of producing no disinfection by-products.
- No additional toxicity was observed in the UV effluent as compared to the pilot influent.

Because UV disinfection depends on light penetration, UV radiation would have limited ability to treat CSO flow due to high suspended solids. CSO waters also contain material that can foul lamps and increase maintenance costs. In addition, a facility using UV disinfection must be designed to handle peak flows unless some form of equalization is provided.

Advantages: Fewer health and safety risks than chlorination. Does not produce chlorine in discharge.

Disadvantages: Less effective when high levels of suspended solids are present. Higher capital and operation and maintenance costs than other disinfection technologies. Large facilities are required for high peak flows.

3.6.2.2 Chlorination / Dechlorination

Chlorination has been used since 1855 to disinfect wastewater in the United States and is the most commonly applied disinfection technology in the country. It is easily available in several forms, inexpensive, and effective against bacteria – although not fully effective against viruses. Disinfection is intended to protect human health; however, chlorination can create serious concerns for communities, operators, and aquatic ecosystems.

Due to the high rates and volumes of wet-weather flows, chlorine treatment often creates a high chlorine concentration, and thus, a high level of toxic by-products and leftover chlorine in the receiving waters.

Recently, regulations have required more wastewater treatment plants and CSO facilities to add a dechlorination process that uses gaseous sulfur dioxide or sodium bisulfite to remove chlorine before it enters the receiving water. On average, dechlorination will add about 30 percent to the cost of chlorination.

Disinfection of high volumes from CSOs would require large quantities of chlorine. The cost and availability of chlorine, the high risks of transportation of toxic chlorine through the community, and risks of gas leaks have led researchers to look for new, alternative disinfection technologies. Hypochlorite is, in general, more expensive than gaseous chlorine. It is, however, easier to handle, more safely stored in on-site tanks, and immediately available for use, but does degenerate over time.

Research indicates that high concentrations of suspended solids can reduce disinfection efficiency by shielding bacteria from the disinfecting agent. However, studies in Boston and Columbus, GA indicated that the major factors influencing chlorine disinfection are the dose, contact time, and mixing intensity. Given its ability to disinfect under higher suspended solids concentrations, the city may want to consider sodium hypochlorite for disinfection of CSOs and wet-weather flows at the AWT plants.

Advantages: Effective against bacteria. Easily available. Widely used. Inexpensive.

Disadvantages: Longer detention time and dechlorination required. Health concerns. Production of chlorinated by-products. Public safety and security concerns.

3.6.2.3 Ozonation

Ozone has been used as a disinfectant for almost as long as chlorine, although primarily for treating drinking water. Ozone disinfection is preferred over chlorination in Europe, where it has been used since 1906. In the early 1970s, design engineers in the United States began to evaluate ozone as an alternative to chlorine for wastewater disinfection. However, because ozone is generally more expensive to produce and must be generated on-site and used immediately, it has been considered a less attractive alternative to chlorine than UV disinfection.

Ozonation was used at the Belmont AWT plant from approximately 1980 to 1994. The plant was converted back to chlorination/dechlorination by the White River Environmental Partnership (WREP) in 1995. However, a project that will be completed in 2006 will restore ozone disinfection at both AWT plants. It is generally acknowledged that ozonation is effective against virtually all organisms in the final effluent, including viruses and protozoan cysts, as well as organisms resistant to chlorination.

Ozone is produced by a corona discharge that is similar to the natural lightning discharge in an electrical storm. Within an ozone generator, a high voltage is imposed across a discharge gap in the presence of an oxygen-containing gas. The resulting electrical discharge produces ozone. The reaction creates substantial quantities of heat that must be quickly removed to keep the ozone from decomposing back into oxygen. To reduce the heat, most commercial ozone generators are water-cooled.

After generation, an oxidation-resistant diffuser provides immediate distribution of ozone into the wastewater effluent stream. Because ozone is a more powerful chemical oxidizing agent than chlorine, it can achieve disinfection at shorter contact times.

Advantages: Shorter contact time than required by chlorination. Increased removal of biological oxygen demand, chemical oxygen demand, total suspended solids and color. Ozone dissipates rapidly, eliminating acute toxicity to biota. Provides a supersaturated dissolved oxygen concentration to the effluent. Eliminates other pollutants that are not affected by biological treatment.

Disadvantages: Operation and maintenance costs are high because of inherent inefficiencies in process. Ozone must be produced on-site and used immediately. Not commonly used for treating CSOs.

3.6.2.4 Peracetic Acid (PAA)

Peracetic acid (PAA) is produced by the reaction of hydrogen peroxide and acetic acid and is the newest disinfection alternative for applications in North America. There are no known harmful by-products generated by the PAA disinfection process. PAA breaks down to oxygen and acetic acid, and thus, it does not present the risk of an undesired residual in the receiving waters. Although these characteristics would seem to encourage intensive investigation of this alternative disinfectant, to date there has not been much research done in the area of its application for CSO disinfection. Although PAA disinfection was investigated at the Columbus, Georgia Advanced Demonstration Facility (Boner and Turner, 1996), there are no known full-scale wastewater treatment facilities using PAA for CSO disinfection in the United States.

Several PAA pilot-scale studies were performed in Europe in the early 1990s. In general, several studies indicate PAA can be an effective disinfectant for wastewater applications. However, although PAA is effective against total coliforms, a recent study showed it to be ineffective against *Giardia* and *Cryptosporidium* parasites. PAA disinfection was discarded from further consideration because its effectiveness is questionable; and few, if any, U.S. wastewater treatment facilities use it.

Advantages: Environmentally safe. Used in southern Europe.

Disadvantages: Not tested in the United States. Level of effectiveness is questionable compared to the more traditional disinfection operations.

3.6.3 CSO Outfall Technologies

The following technologies could be installed at the site of a CSO outfall to remove some pollutants:

- Enhanced High Rate Clarification
- Swirl concentrators (vortex separators)
- Mechanical screens (weir mounted)
- Netting systems
- Trash racks

Disinfection also could be used in combination with these technologies to treat discharges at CSO outfalls. Currently, none of the city's CSO outfalls are equipped for disinfection.

3.6.3.1 Enhanced High Rate Clarification

Please see discussion of this technology in Section 3.6.1.2.

3.6.3.2 Swirl Concentrators (Vortex Separators)

Vortex separators (shown in **Figure 3-6**) are physical treatment devices that promote settling of solids from wet-weather flows. They are referred to as "swirl" concentrators because the flow swirls around the inside of the circular basin, causing a vortex at the center. The centrifugal effect forces solids to the outside wall of the basin where velocities are lower and settling can occur. The device concentrates solids and removes them through a drain, while effluent passes over a weir at the top of the device. Since overloading the unit decreases the performance, each unit is provided with an overflow weir to relieve peak flows and protect the unit. One important advantage of a vortex unit is that it operates completely on hydraulics, requiring no moving parts. This allows the unit to operate unattended during a storm event. However, it does require regular cleaning and maintenance between storms.

A performance review of swirl concentrators has recently been conducted by the Water Environment Research Foundation (WERF, 2002). Evaluation of the net suspended solids removal from case studies and literature indicate that net removals from 5 to 15 percent are typical for vortex separators.

Advantages: Can operate unattended during a storm. Effective at removing grit, heavy suspended solids and floatables. Can provide detention for disinfection. No moving parts.

Disadvantages: Poor net removal of suspended solids and BOD. No bacterial improvement. Negligible ammonia removal.

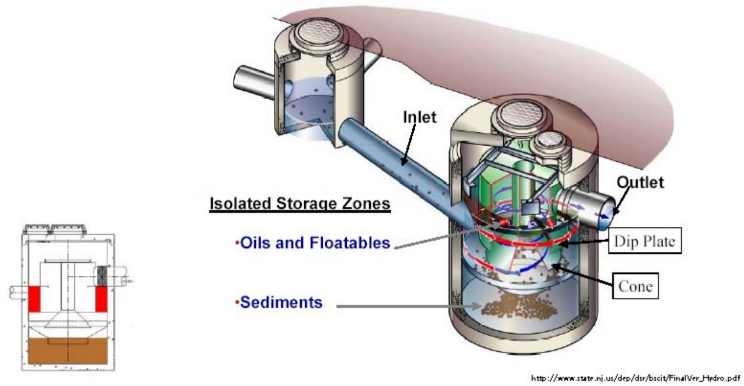

Figure 3-6
Swirl Concentrator (Vortex Separator)

3.6.3.3 Mechanical Screens (Weir-Mounted)

Weir-mounted mechanical screens can remove floatables and some solids from CSOs. They pose several advantages over trash racks or typical mechanical screens. An advantage of this type of screen over trash racks is its ability to be self-cleaning. This can be a significant advantage when compared to the maintenance requirements and the potential for flooding caused by a clogged static screen.

Another advantage of a weir-mounted screen over a typical mechanical screen (climber screen, cog screen, or rake screen) is the low headroom requirement. Most weir screens can be retrofitted into an existing overflow chamber with little to no structural modifications. Typical mechanical screens require a separate chamber to house and protect the screens.

Weir screens can be used in two types of configurations. For weir screens to be considered a low-cost technology for CSO control, they must be installed in an existing overflow chamber on a weir that is typically 5 feet in length or less. Weir screens also can be installed in specially constructed chambers at lengths exceeding 20 feet. However, this technology would not be low cost.

Advantages: Removes floatables. Self-cleaning. Can be retrofitted to existing overflow chambers. Low capital cost. Allows for emergency overflows if screen becomes clogged.

Disadvantages: Not feasible in all CSO outfalls. High operation and maintenance costs. Negligible removal of BOD, TSS, ammonia and bacteria.

3.6.3.4 Netting Systems

Disposable nets can provide basic control to capture floatables at a CSO outfall. Netting systems involve mesh nets that are attached to a CSO outfall to capture floatable material as the CSO discharges into the receiving water. The nets are nylon mesh bags that can be concealed inside the CSO conduit.

Advantages: Captures floatables inexpensively. Can provide a base level of control at some CSO sites.

Disadvantages: High operation and maintenance costs. Negligible removal of BOD, TSS, ammonia and bacteria.

3.6.3.5 Trash Racks

Trash racks or static screens can be located on top of an overflow weir or near the outfall. These devices are inexpensive but usually incur high maintenance costs due to their tendency to become clogged. If these devices bind, serious flooding and sewer backups can occur. They also require manual cleaning on a very frequent basis (usually after every storm) to prevent decreased overflow capacity during later storms.

Static screens were installed in outfall locations around the City of Louisville and became almost completely clogged with leaves from fall runoff. Because of the high maintenance needed to constantly clean the screens, the city decided to remove them.

Advantages: Captures floatables. Low capital cost.

Disadvantages: High operation and maintenance costs. Potential for serious flooding and sewer backups. Negligible removal of BOD, TSS, ammonia and bacteria.

3.7 In-stream Oxygenation Methods

The following options can be used to add oxygen to a stream at critical points where dissolved oxygen levels tend to be low.

3.7.1 Dam Modifications/Removal

Modifying or removing dams can reduce pockets of low dissolved oxygen in a stream. As water passes over a dam, the turbulence causes oxygen to be added. However, dams also create upstream stagnant pools that can have low dissolved oxygen. Solids also can accumulate behind the dam. Boulevard Place dam on Fall Creek and the Perry K (Chevy) and Stout dams on White River have been identified for possible removal or modification to reduce solids accumulation and oxygen depletion.

Advantages: Can increase dissolved oxygen and prevent solids from accumulating upstream from the dam. Returns stream to a more natural state. Improves biological habitat.

Disadvantages: Removal is temporarily disruptive to stream. Costs vary depending on the stream.

3.7.2 Sidestream Aeration/Fountains

Sidestream aeration or fountains can be located where the dissolved oxygen in the streams is most critical during storm events. Sidestream aeration involves a high capacity pumping station that pumps a portion of the stream to an elevated pool. The flow is aerated as it cascades over step-like structures back to the stream. Five of these stations were put into operation along the Calumet-Main channel waterway system in Chicago. Fountains also have been used to provide stream aeration and to enhance the aesthetics of the stream.

Advantages: Increases dissolved oxygen at critical points along a stream. Aesthetically pleasing alternative.

Disadvantages: High capital cost. High operation and maintenance requirements. Construction is disruptive to stream.

3.8 CSO Technology Screening and Evaluation

As noted in Section 1, the City of Indianapolis submitted its CSO Long-Term Control Plan and Water Quality Improvement Report in April 2001 to the U.S. Environmental Protection Agency (U.S. EPA) and Indiana Department of Environmental Management (IDEM). Based on the city's initial evaluation of available CSO control technologies and the characteristics of the city's sewer system, the plan called for the construction of new storage/conveyance facilities along most CSO-impacted waterways and upgrades to the AWT plants to manage peak wet-weather flows. The city received comments on the plan from U.S. EPA in June 2001. Comments related to the screening of CSO control technologies included:

- The city must obtain additional CSO monitoring data to calibrate and verify the CSO collection system model and revise its LTCP to reflect those data.
- The city should analyze the cost-effectiveness of measures that would achieve disinfection, as opposed merely to measures that achieve certain levels of capture.
- The cost-benefit of realistic combinations and sizes of controls should have been evaluated, instead of generic, one-technology assumptions.
- The city's cost-benefit analysis for bacteria control should include evaluation of the benefits of reducing bacteria levels, even if the reduced levels are above the water quality standards. For example, an *E. coli* count of 1,000/100 mL in a water body poses less human health risk than a count of 100,000/100 mL.

The city began meeting with U.S. EPA in August 2001 to begin addressing those comments and others. The negotiations included representatives from IDEM, who submitted their comments on the LTCP in June 2002. The city and regulatory agencies worked together to address the agencies' comments through a step-by-step process, which is described below.

3.8.1 Model Re-Calibration and Verification

In order to address U.S. EPA's comments, the city first had to obtain the agencies' concurrence in and approval of both the CSO collection system model, which is used to estimate CSO flows and size facilities, and the in-stream water quality model, which evaluates the water quality benefits of various CSO control technologies. In the summer of 2001, the city initiated a Supplemental Flow Monitoring and Sampling and Analysis Program. This program utilized twice as many flow monitors and collected end-of-pipe samples to determine constituents found in Indianapolis CSOs. Sufficient data was collected during 2001 to allow for recalibration of the CSO collection system model in early 2002. On June 28, 2002, U.S. EPA sent a letter of approval of the recalibrated CSO collection system model so that the city could proceed to use the model to evaluate CSO control technologies.

Following approval of the CSO collection system model, the in-stream water quality (hydrologic) model was recalibrated by the city and approved by U.S. EPA on August 28, 2002. The models and the recalibration/reverification are described in more detail in the "Indianapolis CSO LTCP Hydraulic and Water Quality Modeling Report."

3.8.2 Re-evaluation of CSO Control Technologies

Pursuant to its June 2001 comments, U.S. EPA asked the city in September 2001 to perform additional evaluation of CSO control technologies for their ability to reduce bacteria discharges to the streams. U.S. EPA representatives said they felt the city had prematurely eliminated remote treatment technologies because of concerns those technologies would not meet dissolved oxygen requirements. The city agreed to perform additional evaluations of 1) systemwide remote treatment facilities and 2) a hybrid alternative that would combine storage/conveyance technologies with remote treatment.

The re-evaluation of control technologies began after the model was re-calibrated, verified and approved by U.S. EPA in the summer of 2002. Because the model re-calibrations resulted in a 10 percent reduction to estimated systemwide CSO volumes, the city needed to re-analyze the storage/conveyance technology in order to provide a valid side-by-side comparison with the other technologies. The city defined two control technologies that would be evaluated for the basic hybrid technology. Therefore, a total of five control technologies were evaluated:

- Control Technology 1 - Storage and conveyance with treatment at AWT plants, plus AWT plant upgrades
- Control Technology 2 – Multiple remote EHRC treatment facilities with UV disinfection, plus AWT plant upgrades
- Control Technology 3 – Hybrid combination of storage/conveyance sized at 12 untreated overflows per year and EHRC with UV disinfection for greater levels of control, plus AWT plant upgrades
- Control Technology 4 – Hybrid combination of storage/conveyance at 12 untreated overflows per year and screening with chlorine disinfection/dechlorination for greater levels of control, plus AWT plant upgrades
- Control Technology 5 – Total sewer separation

Individual technologies were developed and screened for five different overflow frequencies: 12 overflows per year, 6 overflows, 4 overflows, 2 overflows, and 0.5 overflows (1 overflow every two years).

The initial screening process, conducted from August to December 2002, evaluated the effectiveness of various technologies without considering costs or cost-benefit comparisons. In January 2003, the city met with U.S. EPA and IDEM to present the following information:

1) A summary of the re-calibrated CSO collection system model results, showing CSO discharge volumes;

2) Results of the analysis and modeling of the updated in-stream water quality data;

3) Results of the evaluation of the five control technologies on a systemwide and individual stream basis. This evaluation was based upon the following factors:

- Percent annual overflow capture vs. size of storage facilities
- Annual overflow frequency vs. size of storage facilities
- Percent annual overflow capture vs. percent reduction of annual BOD load
- Annual overflow frequency vs. percent reduction of annual BOD load
- Percent reduction of annual *E. coli* bacteria load vs. control technology
- Percent annual overflow capture vs. days of exceedance of the daily maximum *E. coli* bacteria standard (235 colonies/100 mL)
- Annual overflow frequency vs. days of exceedance of the daily maximum *E. coli* bacteria standard (235 colonies/100 mL)
- Percent annual overflow capture vs. days above two *E. coli* bacteria benchmarks (235 colonies/100 mL and 2,000 colonies/100 mL)
- Annual overflow frequency vs. days above two *E. coli* bacteria benchmarks (235 colonies/100 mL and 2,000 colonies/100 mL)

4) Results of the preliminary evaluation of control technologies against additional evaluation criteria related to neighborhood issues, technical issues, operational issues and water quality issues. These criteria, shown in **Table 3-2**, were developed in 2002 with the assistance of advisory committees, U.S. EPA, and IDEM. This evaluation identified issues of concern for each control technology.

The major findings of this analysis were:

- Control Technology 1, storage and conveyance, was the most effective technology for the removal of BOD from CSOs, followed by the hybrid technologies and

Table 3-2
Evaluation Criteria

Neighborhood Issues
Siting Concerns
How close are facilities to homes, parks, schools, roads, etc.?
How difficult would it be to site this alternative at projected locations?
What effect would this alternative have on the existing area?
Safety and Security
Are there public safety issues associated with the proposed alternative, such as use of chemicals for treatment, creation of habitat for vector/nuisance populations (i.e. mosquitoes and flies)?
Are there security issues, such as potential for vandalism, terrorism, sabotage, etc.?
Neighborhood Disruption (Construction)
How much disruption will be caused to the use of streets, sidewalks, parks, yards, etc., during construction?
How long will the disruption last?
Aesthetics
What visual impact will the alternative have on the existing landscape?
Can the alternative be seen from a home or public gathering place, such as a park?
Can the design of any new facilities consider/incorporate surrounding architecture, landscaping, neighborhood themes, etc.?
How will environmental justice concerns be addressed?
Noise
How much and when will noise occur during construction?
How much noise will be present in the long-term from operating procedures such as pumps, blowers, etc.?
Odor
Are odors expected to be reduced in surrounding areas during long-term operation?
Are odors in the area going to be increased during long-term operation?
Truck Traffic (Operation)
How frequently will trucks travel through a neighborhood for regular operation and maintenance activities?
Technical Issues
Siting Concerns
How close are facilities to homes, parks, schools, roads, etc.?
How difficult would it be to site this alternative at projected locations?
What effect would this alternative have on the existing area?
Pollutant Removals
How well does each alternative perform in removing specific pollutants (BOD, TSS, bacteria, and pathogens)?
Consistent Treatment for Variable Flow
Does the alternative have the ability to consistently treat varying flows from different storm events?
Will the alternative provide sufficient disinfection for bacteria control at various flows?
Solids Handling
What means and methods will be used for removing and storing solids contained in the stormwater and/or overflow?
How frequently will solids have to be removed?
Is the removal and storing method automated or does it require on-site attention or operation?

Table 3-2
Evaluation Criteria (continued)

Proven CSO Technology
Does historical field data and information from similar installations demonstrate that this technology can work in Indianapolis?
Does the data demonstrate reliability, acceptable performance, low maintenance, etc.
Permitting Concerns
What is the expected length of permitting time?
How difficult will it be to obtain permits?
Are there issues that might adversely affect permit compliance?
Useful Life of Facilities
What is the expected length of useful life before necessary replacement, upgrade, etc.?
What are the expected cost of operation and maintenance during the useful life of facilities?
Operation Issues
Start-up Capability
What is the expected time of start-up, length of time to achieve effective CSO control, and expected frequency of start-up?
Operations
Will operations require additional staff, special certifications, special equipment, etc.?
Maintenance
How frequently will maintenance activities be required? Will it require additional equipment or staff certification?
How long will the disruption last?
Reliability
Does the equipment have the mechanical reliability to maintain effective operation?
Historical data will be used to evaluate each alternative.
Water Quality Benefits
DO Standards Compliance
Will the alternative achieve dissolved oxygen (DO) compliance, which is necessary for the survival of fish and other aquatic organisms?
Aquatic & Wildlife Benefits
In riverbank ecosystems, the foundations of the food chain for aquatic and most terrestrial animal species are aquatic plants, aquatic insects, and other aquatic macro-and microorganisms. These plants and animals also create recreation opportunities and enhance aesthetic value. Does the alternative promote and sustain aquatic and wildlife benefits?
Peak *E. coli* Level
Alternatives must control and reduce the levels of *E. coli* to help improve water quality.
How well will the alternative reduce peak *E. coli* levels in the receiving stream?
Days of *E. coli* Exceedance
Currently, bacteria levels in the White River in Indianapolis exceed water quality standards at least half the year. This is not only caused by CSO discharges, but also by stormwater runoff, failing septic tanks, wildlife, upstream contributions, etc. Does the alternative reduce the number of days the standards are exceeded?

Table 3-2
Evaluation Criteria (continued)

Solids & Floatables Controls
How well will the alternative reduce or prevent floatables (plastic bottles, containers, floating debris, etc.) and other solid waste (toilet paper, tissue, etc.) from sewer overflows from reaching the receiving streams?
Toxicity Reduction
Certain elements and chemical compounds can be toxic to aquatic life even at low concentrations. Can the alternative reduce concentrations of toxic chemicals in sewage overflows?
Pathogens Reduction
How well would the alternative reduce disease-causing bacteria, viruses, parasites, etc. sometimes found in sewer overflows?
Total Residual Chlorine
Alternatives using chlorine disinfection can possibly contribute residual chlorine to surface waters. Large doses of chlorine in the water are detrimental to aquatic flora and fauna. The severity of impacts associated with chlorine is dependent on the concentration of chlorine discharged and the corresponding amount of dechlorination material used to reduce chlorine residue. Is the alternative likely to significantly increase chlorine levels in the receiving stream?
Financial Issues
Present Worth Cost
Present worth cost is the summation of an alternative's total cost in today’s dollars. What is the total cost, including initial capital cost, long-term operating cost, etc.?
Capital Cost
What is the cost for initial outlay of money for design, permitting, construction, etc.?
Operating Cost
What is the total cost of operation including labor, power cost, chemical cost, equipment replacement cost, maintenance cost, etc.?
Cost per lb. of BOD Removal
BOD is a pollutant of concern for CSO control as it reduces a body of water’s dissolved oxygen. What is the cost per pound of BOD removal, in a form that allows direct comparison between alternatives?
Cost per Percentage of E. coli Removed
E. coli is a parameter of concern for CSO control as it contributes to a water body’s ability to be considered safe for human contact. What is the cost per percentage of *E. coli* removed (e.g., $500,000 achieves 90% removal - vs.- $1,000,000 achieves 95% removal)?
Cost per Additional Day Meeting Bacteria Standard
What is the total cost, divided by the number of additional days the regulatory bacteria levels are met beyond the current number of days when levels meet bacteria standards (on a system-wide basis)?
Unit Cost to Treat
Treatment can be accomplished at existing AWT facilities or at new facilities constructed within the collection system. What is the cost per gallon of sewage that receives partial or full treatment prior to discharging effluent into receiving streams, that meets NPDES permit limits?

remote treatment. All four technologies were equally effective in their reduction of *E. coli* bacteria.

- CSO control alone will not reduce the days of exceedance of the *E. coli* daily maximum bacteria standard of 235 *E. coli* colonies/100 mL without implementing a comprehensive program to reduce other bacteria sources throughout the watershed, such as failing septic systems and stormwater discharges.

- CSO control will reduce the days that in-stream *E. coli* bacteria levels are very high (above 2,000, 5,000 or 10,000 colonies/100 mL).

- When considering neighborhood impacts, technical issues, operational issues, and water quality impacts, storage/conveyance and sewer separation had the fewest issues of concern. However, sewer separation would require significantly more work on private property than storage/conveyance facilities and would cause significantly more disruption during the construction phase. Remote treatment and hybrid control technologies have the most issues of concern with regard to neighborhood impacts.

- Sewer separation would lead to increased pollution from stormwater discharges, a significant source of water quality impairment in Marion County.

- Design storm events cause significant hourly peak flows that must be factored into the sizing of control facilities. These peak flows have a greater impact on facility sizing than overflow volumes. Peak flows are dampened by storage facilities. Conveyance, treatment and pumping facilities that must be sized for peak flows will be large.

- Storage/conveyance and sewer separation are the most established and widely employed technologies for CSO control. Construction of storage/conveyance facilities will require less disruption to neighborhoods than the other control technologies.

This re-evaluation supported the original screening of technologies contained in the 2001 LTCP, which selected storage and conveyance as the preferred technology for CSO control in Indianapolis.

3.8.3 Methodology for Technology Screening by Watershed

Following the results of the 2002 CSO technology re-evaluation, U.S. EPA asked the city to further evaluate technologies by comparing their costs and benefits. In June 2003, the city developed a watershed-based methodology to evaluate both the costs and benefits of the same CSO control technologies.

The methodology involved the following steps:

- Further developing and refining the specific technologies to be evaluated within each watershed
- Further defining, ranking and weighting evaluation criteria
- Running models of the combined system to determine CSO facility sizes and water quality impacts
- Estimating facility sizes and their capital, operation/maintenance and present worth costs (capital plus 20 years' operation/maintenance costs)
- Evaluating the water quality benefits of each technology option
- Numerical scoring of all options at each overflow frequency (12, 6, 4, 2 and 0.5 overflows per year), based upon objective definitions for technical, operating, financial and water quality criteria
- Performing a cost-benefit analysis based upon selected water quality criteria
- Comparing total scores of all options against all evaluation criteria

This methodology is described below and in further detail in *Presentation Supplement for Pleasant Run Alternatives Evaluation* (July 28, 2003).

3.8.3.1 Description of Technologies

The city began the evaluation by developing more specific options within the same five control technologies, but on a watershed basis. For example, under storage/conveyance (Control Technology 1), evaluated options in the Pleasant Run watershed included increased conveyance capacity, storage tunnels, and near-surface storage facilities. These options were screened for the same five overflow frequencies: 12 overflows per year, 6 overflows, 4 overflows, 2 overflows, and 0.5 overflows (one overflow every two years). The first stream evaluated was Pleasant Run, followed by Fall Creek. **Table 3-3** illustrates the control technologies evaluated for Pleasant Run.

The Pleasant Run and Fall Creek watershed evaluations also included the evaluation of partial sewer separation in conjunction with storage/conveyance, remote treatment and hybrid technologies. In order to fully consider all CSO control options, the city evaluated partial separation projects and complete sewer separation to determine what level of sewer separation, if any, would be feasible.

Table 3-3
Pleasant Run Control Technologies Matrix

	UNTREATED OVERFLOW EVENTS PER YEAR					
	12	**6**	**4**	**2**	**0.5**	**0**
CONTROL TECHNOLOGY 1: Storage and Conveyance						
Conveyance via New **Interceptor** with Treatment at AWT Plants	1	2	3	4	5	NA
Storage Tunnel and Dewatering via New Interceptor with Treatment at AWT Plants	6	7	8	9	10	NA
Near-Surface Storage Facilities and Dewatering via New Interceptor with Treatment at AWT Plants	11	12	13	14	15	NA
Limited Near-Surface Storage Facilities and Conveyance via New Interceptor with Treatment at AWT Plants	16	17	18	19	20	NA
CONTROL TECHNOLOGY 2: Remote Treatment Facilities - Remote EHRC and UV Disinfection						
Remote Treatment via EHRC and UV Disinfection **(5 locations)**	21	22	23	24	25	NA
CONTROL TECHNOLOGY 3: Hybrid Technology - Control Technology 1 with EHRC and UV Disinfection						
Conveyance via New **Interceptor** with Treatment at AWT Plants (12 Overflows) and Remote Treatment via **EHRC and UV Disinfection**	X	26	27	28	29	NA
Storage Tunnel and Dewatering via New Interceptor with Treatment at AWT Plants (12 Overflows) and Remote Treatment via **EHRC and UV Disinfection**	X	30	31	32	33	NA
CONTROL TECHNOLOGY 4: Hybrid Technology - Control Technology 1 with Screening and Chlorine Disinfection/Dechlorination						
Conveyance via New **Interceptor** with Treatment at AWT Plants (12 Overflows) and Remote Treatment via **Screening and Chlorine Disinfection** /Dechlorination	X	34	35	36	37	NA
Near-Surface Storage Facilities and Dewatering via New Interceptor with Treatment at AWT Plants (12 Overflows) and Remote Treatment via **Screening and Chlorine Disinfection**/Dechlorination	X	38	39	40	41	NA
Limited Near-Surface Storage Facilities and Conveyance via New Interceptor with Treatment at AWT Plants (12 Overflows) and Remote Treatment via **Screening and Chlorine Disinfection** /Dechlorination	X	42	43	44	45	NA
CONTROL TECHNOLOGY 5: Total Sewer Separation	NA	NA	NA	NA	NA	46
Note: The number in each cell indicates the **number** of the alternative.						

The intent of partial separation projects was not to completely separate the sewers but to separate within a limited area the major public inflow sources (such as catch basins) - those sources that could be easily rerouted from the system. The partial separation concept employed detachment of curbside catch basins within a stretch of each stream to reduce the flow of stormwater within the combined system. Stormwater best management practices to reduce stormwater pollutant impacts to streams were incorporated into these technologies. In Fall Creek, for example, partial separation was considered for approximately 27 percent of the combined sewer area.

Once partial separation projects were defined for a CSO basin, they were modeled to size CSO control facilities for various levels of control. Separation projects were modeled by decreasing the runoff co-efficient (or C-value) in the affected area within each CSO basin. However, an appropriate C-value is difficult to predict since minimal performance data on these types of projects is available. Typical C-values for areas not employing sewer separation in Fall Creek range between 0.3 and 0.5, meaning 30 to 50 percent of rainfall discharges into the combined system as runoff. The C-value is highly dependent upon the number of public and private inflow and infiltration sources impacting the combined system beyond catch basins. Partial separation projects may range from 10 to 50 percent effective in rerouting flows from the combined system (complete sewer separation being 100 percent effective, theoretically).

The facility sizes with partial separation were compared to facility sizes that did not include sewer separation to determine their overall benefit. The model predicted that the flow in the combined system would fall by roughly 20 percent with partial separation. Findings from the modeling analysis were used to size and cost the CSO control facilities. The costing analysis concluded that technologies employing partial separation generally cost more than technologies that did not include sewer separation. Refer to **Figure 3-7** as an example. The least costly alternatives at all levels of control were those that did not employ partial sewer separation.

To complete the analysis, the city evaluated partial separation projects using the evaluation criteria. In general, alternatives that did not employ partial separation received a significantly higher total score when compared to the same alternative with partial separation. Refer to **Figure 3-8** as an example. Additionally, the highest scoring alternative at all levels of control did not employ sewer separation.

Based on the partial separation analysis performed, projects that employed partial separation generally cost more and received lower scores on technical and operating issues than those not employing separation. Partial separation projects might only reduce flow in the combined system by 13 to 25 percent. As a result, the city carried forward the most appropriate CSO controls without partial separation. The city considered and adopted sewer separation projects for small remote CSO areas, and will continue to consider separation as a supplemental project during facility planning of the CSO control projects.

3.8.3.2 Evaluation Criteria

The city used updated evaluation criteria that fell within five categories: technical issues, water quality benefits, financial issues, operating issues and neighborhood issues. The evaluation criteria were presented earlier in **Table 3-2**. At U.S. EPA's request, neighborhood criteria were not used at the watershed-based stage of the evaluation in order to ensure that all technically viable alternatives would survive to the next phase of analysis. Neighborhood issues were used during the alternatives evaluation described in Section 4 of this report.

In order to apply the evaluation criteria to the technologies, the city defined good, fair and poor ratings for each criterion. These definitions enabled the city to rank technologies objectively against their ability to meet each criterion. The city also weighted the criteria, and the five criteria categories, to ensure that the most valued criteria would have more weight in the technology screening. **Table 3-4** illustrates the weighting of criteria categories against each other in a pair-wise comparison.

The pair-wise comparison evaluated each category against the others, assigning numeric scores to quantify the value placed on one category compared to another. For example, in the first row of **Table 3-4**, technical issues ranked much lower in value to the city than water quality benefits, and therefore received a score of "1" when compared with water quality. Continuing along the first row, technical issues ranked much lower than financial issues, with a score of "1", and somewhat lower than operating and neighborhood issues, receiving a "2" when compared to those categories. In the second row, water quality issues ranked much higher than engineering issues (scoring a 5), somewhat higher than operating and neighborhood issues (4), and about the same as financial issues (3). In this way, each category was scored against the others, creating a category weight (sum of all the scores) and a rank (1st through 5th).

Through this process, the city determined that financial issues and water quality benefits were the highest-ranking

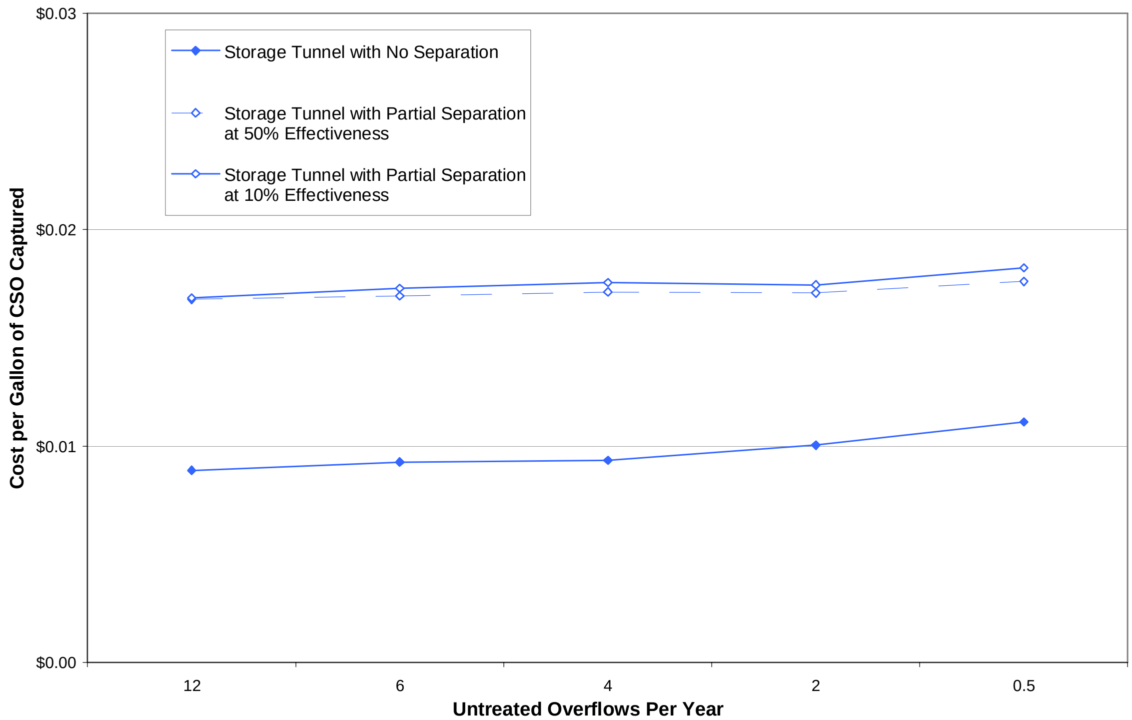

Figure 3-7
Partial Separation: Cost per Gallon of CSO Captured

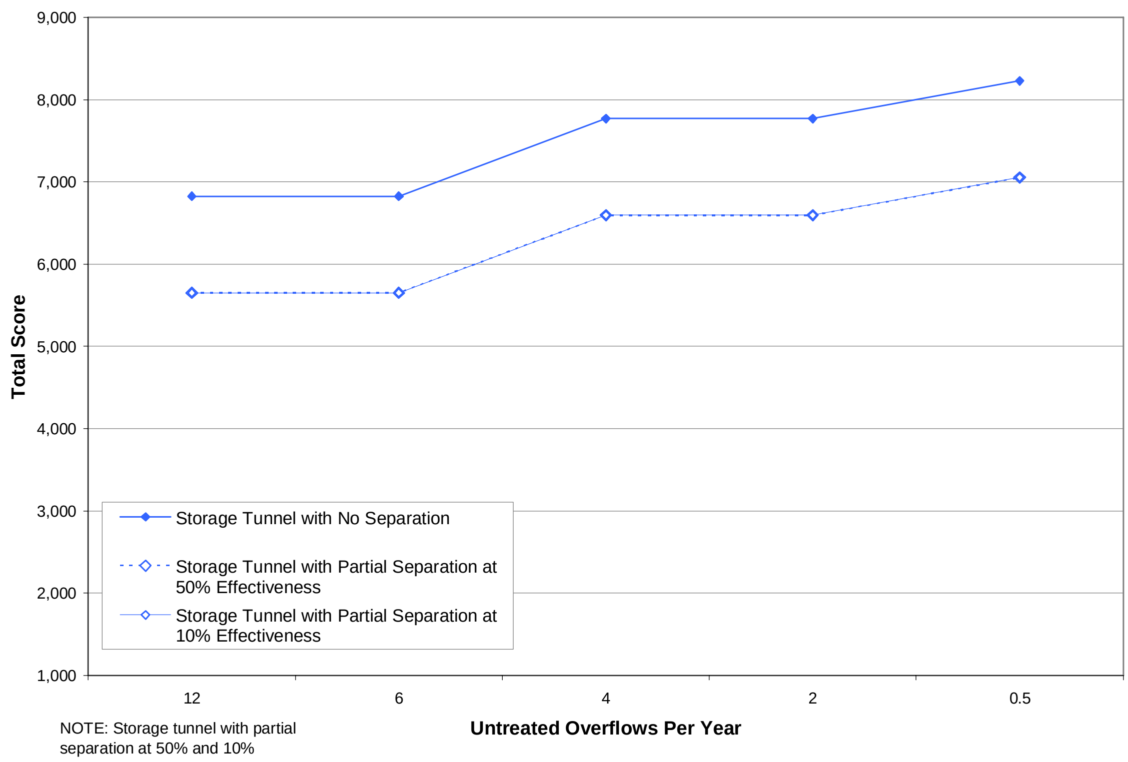

Figure 3-8
Partial Separation: Total Scores by Technology

Table 3-4
Criteria Category Ranking

Criteria Categories	Technical issues	Water quality benefits	Financial issues	Operating issues	Neighborhood issues	Category Weight (Sum)	Rank
Technical issues		1	1	2	2	6	5
Water quality benefits	5		3	4	4	16	2
Financial issues	5	3		5	4	17	1
Operating issues	4	2	1		3	10	4
Neighborhood issues	4	2	2	3		11	3

Key:
1 = Category in row ranks *much lower than* category in column
2 = Category in row ranks *somewhat lower than* category in column
3 = Category in row ranks *same as* category in column
4 = Category in row ranks *somewhat higher than* category in column
5 = Category in row ranks *much higher than* category in column

categories, thus giving them greater weight in the screening of technologies. The financial issues category received a weight of 17 and water quality benefits a 16, compared to 11 for neighborhood issues, 10 for operating issues and 6 for engineering issues.

Within each category, individual criteria also were evaluated through the same pair-wise comparison to develop weighting factors for each individual criterion. The highest-ranking criteria resulting from this process were predominantly in the water quality and financial categories, including days of *E. coli* exceedances, dissolved oxygen compliance, present worth cost, and peak *E. coli* levels. Therefore, these criteria received greater weight in the overall scoring of technologies. For the detailed results of the criteria ranking and weighting, see *Presentation Supplement for Pleasant Run Alternatives Evaluation*, July 28, 2003.

3.8.3.3 CSO Collection System Analysis and Facility Sizing

The city's evaluation reflected additional CSO collection system modeling performed to support the watershed screening process. Hydraulic analysis was carried out using the NetSTORM model of the city's combined sewer system. The model predicted the CSO discharge volumes and flowrates that would have to be managed by each CSO control facility. This output was then used to (1) size and preliminarily site the facilities and develop their associated costs and (2) carry out the in-stream water quality analysis.

3.8.3.4 Water Quality Analysis

Using the updated CSO collection system and the in-stream water quality model, the city evaluated the water quality benefits of the CSO control technologies. The water quality analysis was performed to demonstrate results attained by the current system, to estimate potential non-CSO background improvements to meet dry weather compliance goals, and to evaluate the benefits of various CSO control alternatives. The analysis was based upon the following factors:

- CSO flows and pollutant loading, including percent capture, average annual CSO frequency, average annual CSO volume removed, average annual CSO discharge remaining, and average annual BOD and *E. coli* loads
- In-stream modeled water quality benefits, including impacts on dissolved oxygen, maximum bacteria concentrations, *E. coli* geometric mean, compliance with the 235 cfu/100 mL *E. coli* standard, and ability to reduce the number of days *E. coli* levels exceed 2,000; 5,000; and 10,000 cfu/100mL targets

3.8.3.5 Cost-Performance Analysis

Costs for the CSO control technologies at various levels of control were evaluated based on the city's April 23, 2004, cost memorandum, "Cost Estimating Procedures for Raw Sewage Overflow Control Alternatives Evaluation." The following costs were generated for evaluation: (1) capital cost, (2) operation and maintenance cost, (3) present worth cost, (4) cost per pound BOD removal, (5) cost per percentage *E. coli* removal, (6) cost per additional day meeting bacteria standard, and (7) unit cost to treat.

At U.S. EPA's request, the city also generated cost-performance curves to illustrate each alternative's cost per gallon of CSO flow captured, cost per pound of BOD removed, and cost per unit of *E. coli* bacteria removed. While these cost-performance curves provided important information, the ranking and screening of technologies in this step were based upon a process that analyzed the technologies based upon 27 criteria (see **Table 3-2**), weighted and ranked in relation to each other.

3.8.3.6 Total Score Analysis

Using the criteria definitions and the criteria weight factors, the city developed scores for each technology at the five selected levels of control. This score represents a general sense of how well a technology is expected to meet the project goals, but does not necessarily identify the single best technology or combination of technologies for the watershed. In this manner, the city identified the most promising technologies that would be further developed and evaluated in the next step of the alternative evaluation process.

The results of employing the above methodology to analyze technologies for Pleasant Run and Fall Creek are described below.

3.8.4 Pleasant Run Results

Table 3-3 illustrated the CSO control technologies considered in the Pleasant Run watershed at the five selected levels of control. This section summarizes the results of the CSO control technology screening for Pleasant Run.

3.8.4.1 Water Quality Results

Results of the water quality analysis for Pleasant Run are as follows:

- ***BOD and E. coli Loads**:* Pleasant Run's current system contributes approximately 245,000 pounds of BOD and 1.5 x 10^{16} cfu of *E. coli* bacteria per year to Pleasant Run. In general, storage/conveyance removes a greater BOD load from Pleasant Run than remote treatment or total sewer separation. Higher levels of CSO control (0.5 overflows) have the lowest *E. coli* bacteria loads while the most significant reduction in *E. coli* bacteria is with total sewer separation.
- ***DO Concentration:*** Pleasant Run currently meets water quality standards for dissolved oxygen. Since dissolved oxygen levels are good in Pleasant Run, no significant improvement in dissolved oxygen occurs with CSO controls.
- ***E. coli Bacteria Concentration**:* Maximum *E. coli* bacteria counts in Pleasant Run currently fall between 100,000 and 400,000 cfu per 100 mL for a range of evaluation storms. Storage/conveyance (at 4 or 2 overflows) would reduce the peak *E. coli* levels to at or below 100,000 cfu per 100 mL. Remote treatment has similar results; CSO counts fall below 50,000 cfu per 100 mL at 4 or 2 overflows.
- ***E. coli Geometric Mean**:* Pleasant Run is listed on the 303(d) list as impaired for *E. coli*. Under current conditions, Pleasant Run has a geometric mean of 448 cfu/100 mL for *E. coli*. Background improvements, such as septic tank elimination and storm sewer improvements, are expected to achieve compliance with the *E. coli* bacteria standard during dry weather, improving the overall geometric mean to a projected 197 cfu/100 mL. CSO controls would further reduce the geometric mean, ranging from 149 cfu/100 mL at 12 overflows per year to 127 cfu/100 mL at 0.5 overflows. However, the reduction of the geometric mean is dependent on the number of overflows, and not the technology used.
- ***E. coli Days of Exceedance:*** The city's analysis concluded that CSO controls alone will not improve the number of days that Pleasant Run will meet Indiana's 235 cfu/100 mL single sample maximum standard for *E. coli*. Stormwater discharges will still cause frequent exceedances of this standard. The city's analysis also demonstrated that CSO controls will help reduce the number of days that in-stream *E. coli* levels exceed the higher targets of 2,000, 5,000, and 10,000 cfu/100 mL.

3.8.4.2 Cost-Performance Results

Cost per Gallon of CSO Flow Captured: Capture includes conveyance, storage and treatment. For any given level of CSO control, such as 12 overflows per year, all technologies will capture the same annual average volume, except for sewer separation. An interceptor with treatment at the AWT plants (Technologies 1-5 on **Table 3-3**) had the best cost-performance results for reducing CSO discharges.

Cost per Pound of BOD Removed: The annual BOD removed is highest for storage technologies, which can be dewatered and treated at the AWT plants, whereas Control Technology 2 (treatment with EHRC) has the lowest annual BOD removal rates. An interceptor with treatment at the AWT plants (Technologies 1-5) had the best cost-performance for BOD removal.

Cost per Unit of *E. coli* Bacteria Removed: An interceptor with treatment at the AWT plants (Technologies 1-5) had the best cost-performance for removal of *E. coli* bacteria.

3.8.4.3 Total Score Results

Total scores based on the criteria led to the following general conclusions on the control technologies evaluated:

- Technology 1 (storage and conveyance) ranks highest across all levels of control. A storage tunnel appears to be favored over near-surface storage facilities.
- Storage and conveyance provides reliability, less remote maintenance, improved water quality, and reduced human health risk in Pleasant Run at less cost.
- Some hybrid technologies (Technologies 3 and 4) score relatively well on cost-effectiveness criteria, but not as well as storage and conveyance technologies. These technologies also score poorer on reliability, operating issues and other issues, giving them poor overall scores in comparison to storage and conveyance options in Pleasant Run.
- Due to cost, operating and technical issues, Technology 2 (remote treatment) scores poorly in Pleasant Run.
- Technology 5 (sewer separation) scores poorly on financial issues.[2]

[2]*For additional information on the city's analysis of Pleasant Run CSO control technologies, see the following documents: Methodology for Long-Term Control Plan Alternatives Evaluation, Pilot Study - Pleasant Run Watershed (June 2003); Presentation Supplement for Pleasant Run Alternatives Evaluation (July 28, 2003); Memorandum: Pleasant Run Alternatives Evaluation, Response to EPA/IDEM Questions (September 8, 2003).*

3.8.5 Fall Creek Results

Table 3-5 illustrates the CSO control technologies considered in the Fall Creek watershed.

3.8.5.1 Water Quality Results

Results of the water quality analysis for Fall Creek are as follows:

- ***BOD and E. coli Bacteria Loads:*** Fall Creek's current system contributes approximately 825,000 pounds of BOD and 4.7×10^{16} cfu of *E. coli* bacteria per year to Fall Creek. In general, storage/conveyance removes a greater BOD load than remote treatment or total sewer separation. The higher levels of control and total sewer separation show the most significant reduction in *E. coli* bacteria.
- ***DO Concentration:*** Some segments of Fall Creek do not achieve the state's minimum 4.0 mg/L and the daily average 5.0 mg/L water quality standards for dissolved oxygen. Based on current system conditions, a dissolved oxygen concentration of 2.0 mg/L is predicted for the one-year storm. In general, storage and conveyance would improve dissolved oxygen at high levels of control (less than 4 overflows) but do not achieve the standard at low levels of control (12 and 6 overflows) without the addition of oxygen-enhancing methods, such as dam removal or aeration. Remote treatment would meet dissolved oxygen standards at all levels of control. Hybrid technologies with EHRC and UV disinfection would achieve the standard except at 12 overflows, while hybrid technologies with screening and chlorine disinfection/dechlorination would not achieve the standard at any level of control. In-stream aeration, dam modifications and other measures could be employed to improve dissolved oxygen concentrations and meet Indiana water quality standards with any technology.
- ***E. coli Bacteria Concentration:*** Maximum *E. coli* bacteria counts in Fall Creek currently fall between 100,000 and 400,000 cfu/100 mL for a range of evaluation storms. Storage/conveyance would not significantly lower maximum *E. coli* levels, but would substantially reduce the annual frequency at which excessively high bacteria counts occur. Remote treatment would reduce the levels to below 100,000 cfu/100 mL at control levels greater than 6 overflows.
- ***E. coli Geometric Mean:*** Based on current system conditions, Fall Creek achieves an all-weather geometric mean of 372 cfu/100 mL *E. coli* bacteria. With back-

Table 3-5
Fall Creek Control Technologies Matrix

	UNTREATED OVERFLOW EVENTS PER YEAR					
	12	**6**	**4**	**2**	**0.5**	**0**
CONTROL TECHNOLOGY 1: Storage and Conveyance						
Conveyance via New **Interceptor** with Treatment at AWT Plants	1	2	3	4	5	NA
Storage Tunnel and Dewatering via New Interceptor with Treatment at AWT Plants	6	7	8	9	10	NA
Near-Surface Storage Facilities and Dewatering via New Interceptor with Treatment at AWT Plants	11	12	13	14	15	NA
Limited Near-Surface Storage Facilities and Conveyance via New Interceptor with Treatment at AWT Plants	16	17	18	19	20	NA
CONTROL TECHNOLOGY 2: Remote Treatment Facilities - Remote EHRC and UV Disinfection						
Remote Treatment via EHRC and UV Disinfection **(6 locations)**	21	22	23	24	25	NA
Remote Treatment via EHRC and UV Disinfection **(1 location)** and Conveyance / Storage Tunnel	26	27	28	29	30	NA
CONTROL TECHNOLOGY 3: Hybrid Technology - Control Technology 1 with EHRC and UV Disinfection						
Storage Tunnel and Dewatering via New Interceptor with Treatment at AWT Plants (12 Overflows) and Remote Treatment via **EHRC and UV Disinfection**	X	31	32	33	34	NA
Limited Near-Surface Storage Facilities and Conveyance via New Interceptor with Treatment at AWT Plants (12 Overflows) and Remote Treatment via **EHRC and UV Disinfection**	X	35	36	37	38	NA
CONTROL TECHNOLOGY 4: Hybrid Technology - Control Technology 1 with Screening and Chlorine Disinfection/Dechlorination						
Storage Tunnel and Dewatering via New Interceptor with Treatment at AWT Plants (12 Overflows) and Remote Treatment via **Screening and Chlorine Disinfection/**Dechlorination	X	39	40	41	42	NA
Limited Near-Surface Storage Facilities and Conveyance via New Interceptor with Treatment at AWT Plants (12 Overflows) and Remote Treatment via **Screening and Chlorine Disinfection** /Dechlorination	X	43	44	45	46	NA
CONTROL TECHNOLOGY 5: Total Sewer Separation	NA	NA	NA	NA	NA	47

Note: The number in each cell indicates the **number** of the alternative.

ground improvements such as septic tank elimination, storm sewer improvements, and streambank restoration, the geometric mean is projected to fall to 292 cfu/100 mL. In addition to these programs, an estimated 2.5 mgd of flow augmentation is necessary to attain the *E. coli* geometric mean during dry weather. CSO controls would further reduce the all-weather geometric mean, ranging from 167-172 cfu/100 mL at 12 overflows per year to 144-149 cfu/100 mL at 0.5 overflows. However, none of the CSO controls would achieve the geometric mean standard of 125 cfu/100 mL, due to the impacts of urban stormwater discharges on this waterway.

- ***E. coli* Days of Exceedance:** The city's analysis revealed that CSO controls alone will not improve the number of days that Fall Creek will meet Indiana's 235 cfu/100 mL single sample maximum standard for *E. coli.* The city's analysis demonstrates that CSO controls will help reduce the number of days that in-stream *E. coli* levels exceed the higher targets of 2,000, 5,000, and 10,000 cfu/100 mL.

3.8.5.2 Cost-Performance Results

Cost per Gallon of CSO Flow Captured: A storage tunnel with treatment at the AWT plant (Technologies 6-10 on **Table 3-5**) and with remote treatment at the downstream end of the watershed (Technologies 26-30) had the best cost-performance for reducing CSO discharges.

Cost per Pound of BOD Removed: Similar to Pleasant Run, the annual BOD removed is highest for storage technologies, which can be dewatered and treated at the AWT plant, whereas treatment technologies have the lowest annual BOD removal rates. A storage tunnel (Technologies 6-10) had the best cost-performance for BOD removal.

Cost per Unit of *E. coli* Bacteria Removed: A storage tunnel with treatment at the AWT plants (Technologies 6-10 on **Table 3-5**) and with remote treatment at the downstream end of the watershed (Technologies 26-30) had the best cost-performance for removal of *E. coli* bacteria.

3.8.5.3 Total Score Results

Total scores based on all criteria led to the following general conclusions on the control technologies evaluated:

- Technology 1 (storage and conveyance) ranks highest across all levels of control. A storage tunnel appears to be favored over near-surface storage facilities. Storage and conveyance provides reliability, less remote maintenance, improved water quality, and reduced human health risk in Fall Creek at less cost.
- Due to operating and technical issues, Technology 2 (remote treatment) scores poorly in the Fall Creek watershed. However, the remote treatment technologies that are combined with a storage tunnel score very well on cost-effectiveness criteria for *E. coli* removal, but not as well on operating and technical issues and BOD removal. These technologies demonstrate one of the lowest costs for all levels of control.
- Some hybrid technologies (Technologies 3 and 4) score relatively well on cost-effectiveness criteria, but not as well as storage and conveyance technologies. These technologies also score poorer on reliability, operating issues and other issues, giving them lower overall scores in comparison to storage and conveyance options in the Fall Creek watershed.
- Technology 5 (sewer separation) scores poorly on financial issues and should not be carried forward.[3]

3.8.6 CSO Technology Screening Conclusions

As the city was completing the Fall Creek technology screening process in December 2003 and January 2004, it noted the following trends:

- Storage/conveyance ranked highest at all levels of control due to reliability, water quality and cost-effectiveness.
- Remote treatment scored poorly due to operating and technical issues, but may be viable combined with a tunnel on Fall Creek or storage on Pogues Run. Remote treatment also carries heightened operational and security concerns.
- Hybrid technologies can score well on cost-effectiveness but never scored as well as storage/conveyance by itself. Screening and disinfection is not very effective and has been questioned by the public.
- Sewer separation scores poorly on financial issues but has merits on smaller, remote watersheds.

By late 2003, the city became concerned that the technology screening process was more lengthy than necessary.

[3]For additional information on the city's analysis of Fall Creek CSO control technologies, see the following documents: *Memorandum: Fall Creek Alternatives Evaluation (November 7, 2003); Memorandum: Fall Creek Alternatives Evaluation, Response to EPA/IDEM Questions (December 11, 2003); Memorandum: Fall Creek Alternatives Evaluation, Response to EPA/IDEM Questions (January 23, 2004).*

Furthermore, the analysis was yielding conclusions similar to those anticipated for each watershed. Rather than proceed with additional analysis of other watersheds, the city proposed, and U.S. EPA and IDEM agreed, that the screening of technologies was complete and the city should move ahead with consideration of CSO control alternatives on a systemwide basis. The analysis of those systemwide alternatives is documented in Sections 4.4 through 4.6.

3.9 Summary

The City of Indianapolis can draw from a wide variety of technologies to better control combined sewer overflows. Many of the technologies evaluated here have been tested and proven in other cities. Indianapolis has evaluated these technologies based on technical issues, operating issues, financial issues and water quality benefits. Based upon comments received from U.S. EPA, the city re-calibrated its CSO collection system and hydrologic models and re-evaluated technologies providing remote treatment of CSO discharges. This work was conducted from August 2001 through January 2004, beginning with an evaluation of technologies based upon non-cost factors and concluding with a detailed watershed-based analysis of technologies based upon various evaluation criteria, including cost and cost-benefit analyses.

An analysis of technologies in the Pleasant Run and Fall Creek watersheds demonstrated that increased storage and conveyance is the most cost-effective technology for CSO control, with the possible addition of an EHRC facility on Fall Creek. Similarities between Fall Creek and Pogues Run led to the conclusion that an EHRC facility at Pogues Run also should be evaluated further. Based upon the conclusions drawn from Fall Creek and Pleasant Run, the city proposed, and U.S. EPA and IDEM agreed, to consider CSO control alternatives on a more systemwide basis. Section 4 summarizes how Indianapolis evaluated the application of these technologies, and combinations of technologies, to specific streams and the city's advanced wastewater treatment plants. Neighborhood issues were considered in this evaluation, including siting concerns, safety and security, neighborhood disruption during construction, aesthetics, noise, odor, and truck traffic during operation. Neighborhood issues, public opinion, overall cost and water quality benefits all were considered in selecting the best alternative for each watershed and for Marion County as a whole.